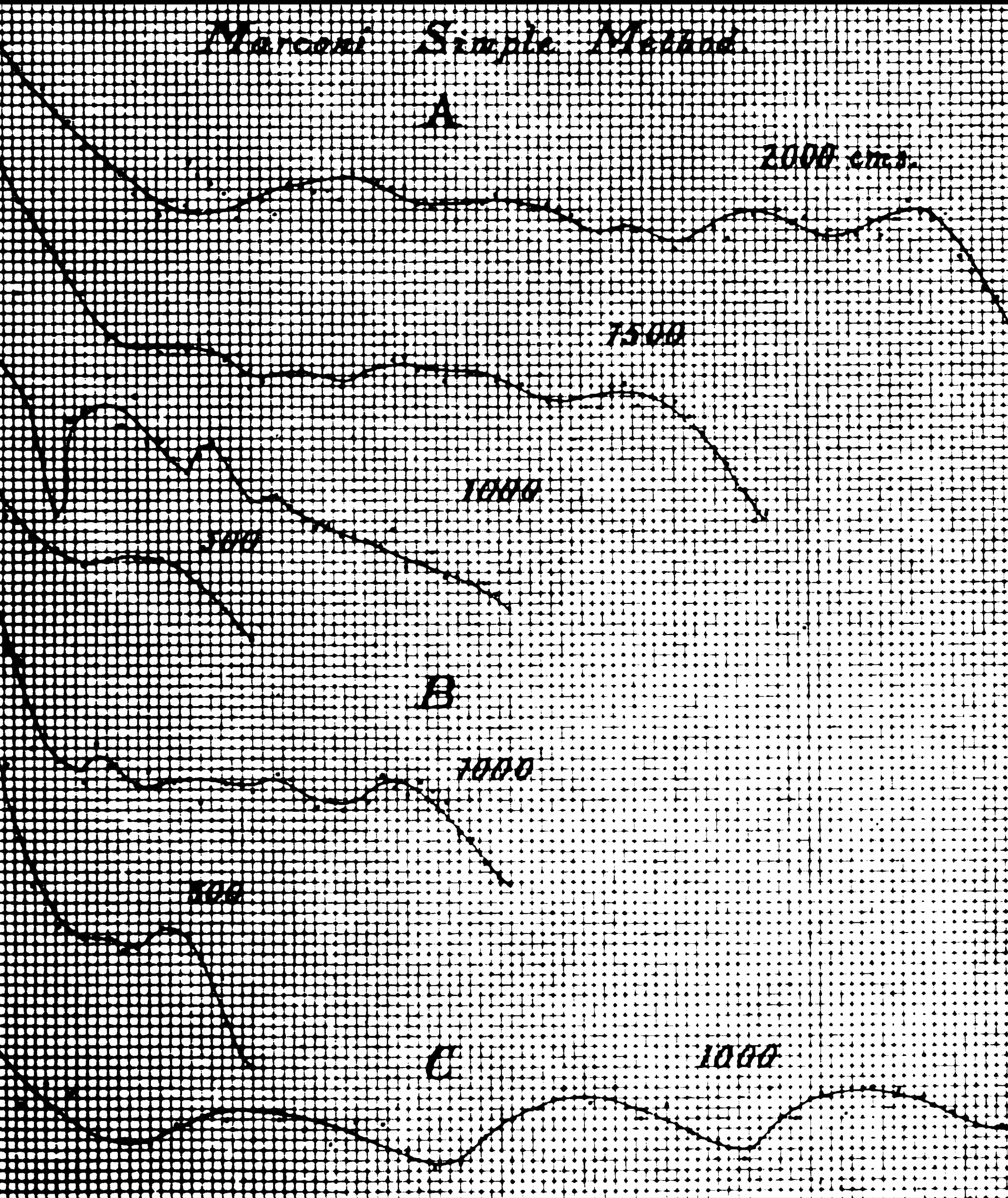

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[FOURTH SERIES.]

ART. I.—*The Variation of Potential along the Transmitting Antenna in Wireless Telegraphy;* by C. A. CHANT.

I. *Introduction.*

IN a former paper* illustrations were given of the manner in which standing waves are formed on a free-ending wire when the electrical disturbance is produced by electrostatic induction from a Hertzian oscillator at the other end of the wire. The present communication contains a somewhat detailed account of an examination of the aërial wire used to radiate the waves in wireless telegraphy; and, in a section at the end, a brief account of a continuation of the former experiments.

The problem of the electrical oscillations about a free-ending wire has been treated from a rigid theoretical basis by Abraham,† who determined the electric and magnetic forces at any point in the field by directly integrating the Maxwellian equations. For the purposes of analysis the wire was considered to have the form of a very elongated paraboloid of revolution, and the field to vary in such a way that the electric lines of force ended perpendicular to its surface. Sarasin and de la Rive,‡ and others had compared the oscillations about a wire to those in an open pipe; but, as Abraham remarks, though the relations are essentially similar, the analogy must not be pushed too far, In the pipe the radiation is from within outwards, and is greatest in the direction of the

* C. A. Chant, The Variation of Potential along a Wire Transmitting Electric Waves; this Journal, xv, p. 54, 1903; Phil. Mag. [6], v, p. 331, 1903.

† M. Abraham, Ann. der Physik, ii, p. 32, 1900.

‡ E. Sarasin and L. de la Rive, Archives des Sciences Physiques et Naturelles, Genève, xxiii, p. 113, 1890.

axis; while in the electro-magnetic case the radiation is from without inwards, being limited by the surface of the wire, and on account of the transversality of the vibrations there is *no* radiation along the axis. Moreover, in the air-vibrations there is a displacement of the entire system of nodes and loops towards the open end, while, with the electrical oscillations, *to a first approximation*, there is no such displacement. On a closer examination, however, there is found to be a displacement of this kind, variable with the frequency. The phase of the advancing waves alters in a discontinuous manner, somewhat as in the vibrations of a plucked string.*

When two wires are used, as in Lecher's arrangement, the radiation in the direction of the axis does not vanish, and the analogy to the open pipe is more marked. There is then a decided displacement of the nodes and loops, well exhibited in an investigation by de Forest.†

The best acoustical analogy to a wire connected at one end to earth or to a large capacity and free at the other seems to be a closed pipe, gas-pressure in the pipe corresponding to potential or charge in the case of the wire. Here there is a displacement of the nodes and loops, but it is very small, and only the odd harmonics are present in the two cases. Of course a rod clamped at one end is similar to the closed pipe.

Birkeland and Sarasin,‡ in their investigation of the field about a free-ending wire, explored with a circular resonator, and found the first node distant from the end by one-half the circumference of the resonator (a result similar to that obtained by Sarasin and de la Rive in their investigation on two parallel wires, and ascribed by them to the geometrical form of the resonator), and other nodes regularly spaced along the wire at intervals equal to twice the diameter of the resonator. The form of the nodal surfaces in the space about the wire obtained by them agrees with that deduced by Abraham.

Slaby's theoretical treatment§ of the problem is much simpler than Abraham's, and from his results he was led to his method of syntonic telegraphy. He takes the so-called "telegraphic equation,"

$$R_1 \frac{\partial i}{\partial t} + L_1 \frac{\partial^2 i}{\partial t^2} = \frac{1}{C_1} \frac{\partial^2 i}{\partial x^2},$$

where i is the current strength at any time at a place x on the

* Helmholtz, Sensations of Tone, p. 54; Rayleigh, Theory of Sound, art. 146.

† L. de Forest, this Journal, viii, p. 58, 1899.

‡ K. Birkeland and E. Sarasin, Comptes Rendus, cxvii, p. 618, 1893.

§ A. Slaby, Lond. Electrician, vol. xlvi, Jan. 18, 1901; also vol. xlix, April 25, 1902.

antenna, and R_1, L_1, C_1, are the resistance, self-induction and capacity per unit length of the wire. A solution* is

$$i = A e^{-\frac{R}{2L}t} \cos\frac{2\pi}{T} t \sin\frac{\pi}{2l} x,$$

where $T = 4\sqrt{LC}$, l is length of wire, A is a constant and R, L, C, relate to the whole length of the wire. The frequency is $1/T$ and $\lambda = 4l$. From this solution it should follow that the disturbance varies according to the simple harmonic law, and that the free end of the wire is a potential loop, the lower end a potential node.

II. *Experimental Arrangements and Results.*

In the present investigation all the wires explored were of bare copper of diameter 7^{mm} and were stretched horizontally on the tops of wooden poles about $1{\cdot}5^{m}$ high and $1{\cdot}6^{m}$ from the wall of the room in which the experiments were made. This room was a large hall, on the first flat, about 22^{m} long, 12^{m} wide and with a ceiling 13^{m} high. The manner of examining the wire at various points in its length was precisely similar to that in the former research. The induction coil and interrupter, the magnetometer and the method of taking readings were identical with those used earlier and need not be described again here.

In most of the work the detector was the one used before, but during the course of the experiments it was broken and another, similar to it and indistinguishable from it in its behavior, was constructed.

The manner of applying the detector to the wire was slightly different. Before, the detector was laid on the top of a carriage moving on ways along the wires, with the little wing, *w*, fig. 1, in a little pocket by the wire; now, a small piece, *c*, of

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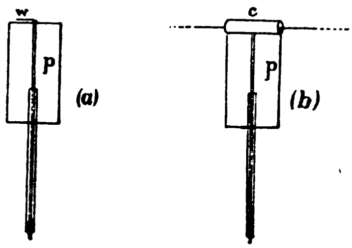

cylindrical hard-rubber rod, in which a groove was made down to the axis, along a plane through the axis, was fastened to the

* See Webster, Electricity and Magnetism, arts. 255, 256.

hard-rubber plate, *p*, by wax, and the detector was then hung on the stretched wire at any place desired.

The curves are plotted from the mean of at least three sets of readings.

The published accounts of the exploration of wires about which electrical disturbances are produced as in wireless telegraphy are not numerous, and, as far as I can learn, in no case has the exploration been at all minute.

In the present investigation three methods, well-known in practice, have been used to excite the oscillations.

Marconi's Simple Method.

This arrangement is illustrated in fig. 2. The "oscillator" in this case consisted of two cylindrical brass rods, AB, CD, 9·5^{mm} in diameter and 12·5^{cms} long, ending in spherical knobs B, C, 3·8^{cm} in diameter. One half of the doublet is shown on

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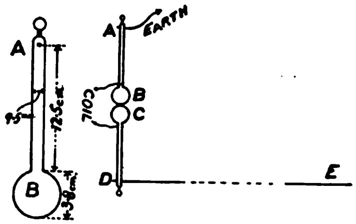

a larger scale at the left-hand of fig. 2. From D led off the antenna DE. In some experiments A was connected to earth, in others a wire similar to DE was attached to A, while in one series this end of the doublet was left entirely free

The knobs B, C were not kept polished, and the spark was about 1·9^{mm} long.

For earth, in the case of wires of lengths 500, 1500 and 2000^{cms}, A was joined immediately to a large sheet of tin, which, along with about two square meters more of sheet metal, was firmly connected to a steam-heating radiator near by. For the wire 1000^{cms} in length the connection from A to the sheet of tin was about 75^{cms} long.

The wire joined to A in place of the earth connection was precisely the same as that acting as antenna and attached to D; and in order to prevent inductive effects between these two wires the former was drawn up in a vertical direction by a cord over a pulley in the ceiling.

The readings were taken at points, usually 20^{cms} apart, from one end of the antenna to the other, the order of the readings in some cases beginning at the free end, in the rest moving towards it.

A general view of the results obtained is given in Table I and fig. 3. In the table the distances of the minima from the free end are given in centimeters, and the less-marked minima are enclosed in brackets.

TABLE I.

Length of antenna. cms.	Distance, in centimeters, of minima from free end of antenna. A With earth connection.	B With equal long wire.	C No earth connection.
500	(175). None	260. None	--------
1000	(120), (375), (500). None	(150), (660). None	130, 425, 715, (1000 ?)
1500	(320 ?). None	--------	--------
2000	None	---- --	--------

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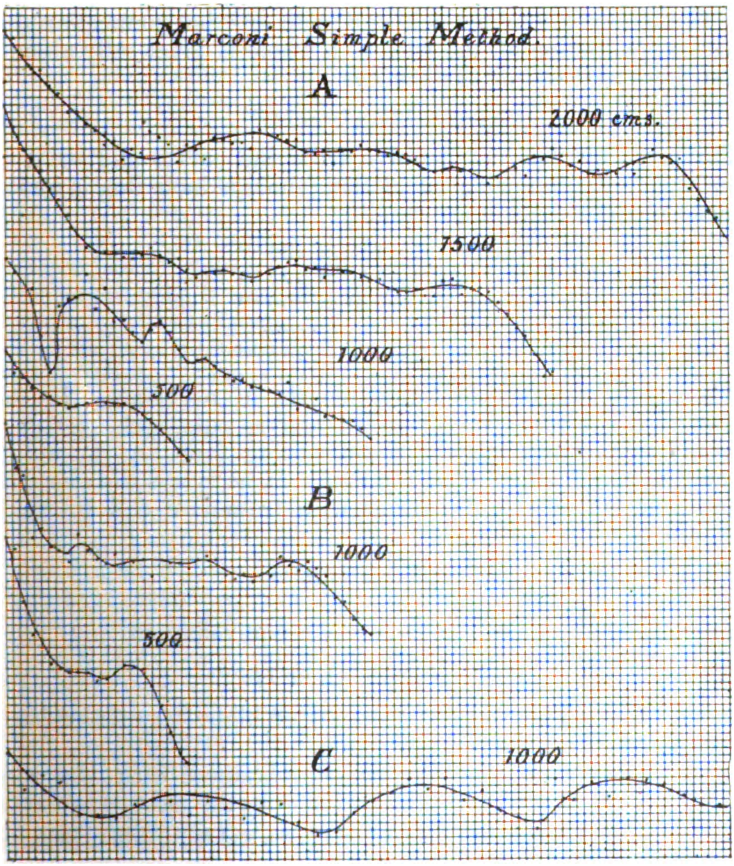

In all the curves abscissas represent distances from the free end and ordinates magnetometer deflections.

It is seen from the curves, that joining to earth one pole of the oscillator is equivalent to adding to that pole a wire similar to the antenna; or, in other words, the earth acts like a plane mirror in optics. This view has been put forward by several writers, especially by Slaby* when offering an explanation of his system of syntonic telegraphy.

In the curve obtained with the antenna of 1000^{cms} connected to earth (see fig. 3), there is a deep minimum at approximately 123^{cms} from the free end, and a second one at 375^{cms}. This would give

$$\begin{aligned} \lambda/2 &= \quad 2\times 123 = 246^{cms} \\ &= 375-123 = 252^{cms} \\ \text{Mean} & \qquad\qquad\quad\; 249^{cms} \end{aligned}$$

In the curve obtained with no earth or other connection the natural oscillation of the wire as a whole is practically absent, but there are minima at distances

$$130,\ 425,\ 725,\ (1000\,?)^{cms}$$

That at 1000^{cms} is not decisive from the curve, and so it is omitted in the following calculation (though including it would make no difference in the result):

$$\begin{aligned} \lambda/2 &= \quad 2\times 130 = 260^{cms} \\ &= 425-130 = 295^{cms} \\ &= 715-425 = 290^{cms} \\ \text{Mean} & \qquad\qquad\quad\; 282^{cms} \end{aligned}$$

These, I believe, are half-wave-lengths of overtones. In the first case the wire was grounded and so only odd overtones would be possible, the one present being probably the ninth, counting the fundamental, the first. If such was the case, the entire length of the oscillating wire from free end to earth should be

$$9\times\frac{249}{2} = 1120^{cms},$$

a result requiring the oscillator to be equivalent to

$$1120-(1000+75),\ \text{or}\ 145^{cms}$$

of the wire. This value appears rather high, but this explanation seems to me the most probable.

I may remark that the curves obtained with the wire 1000^{cms} long, connected to the earth, were the most irregular of

* A. Slaby, Funkentelegraphie, 2d ed., p. 86, and fol. Berlin, 1901.

all secured during the investigation, especially in the space between 100 and 300^{cms} from the free end. A possible cause contributing to this may have been that the electrical disturbance was not produced immediately at the earth end.

In the second case the oscillating wire was free at each end, and so the entire system of overtones was possible. The one present, with half-wave-length of 282^{cms}, seems to be the fourth, in this case the oscillator adding to the wire one-fourth of a wave-length.

It may be questioned why these particular overtones were present, and the others not noticeable. I think it was because the natural period of the oscillator alone was in approximate accord with them, being about one-half that of those exhibited. This would agree with the results of Lindemann,* who found that the waves proper to the oscillator, as well as those of the entire system of oscillator and wires, should be present.

I have not been able to identify the other ripples of the curves.

Slaby† and Braun‡ have both studied the simple Marconi system. The former used a wire about 10 meters long, and explored it with a spark micrometer in which a blunt metal cone was opposed to a flat face of arc carbon. According to the curve he obtained (fig. 1 of his article), there was a standing wave, with potential loops at the ends and a relative node in the middle. In my experiments there is a node at the end of the wire attached to the coil. Slaby concluded that the overtones present were very trifling and that the oscillation emitted was almost a pure fundamental. The fundamental is certainly present in great intensity, but the readings giving it are sometimes scattering, as mentioned above, and the curve is not very smooth. In some cases, too, as already seen, overtones show in considerable strength. Slaby also found that when the pole of the induction coil was joined, not to an end of the antenna but to some other point, the oscillation produced showed considerable distortion. This effect is similar to that noted above in the case of the 1000^{cms} earthed wire.

Braun used a wire 15 meters long stretched horizontally, and from it suspended five small Geissler tubes, each with a wire 50^{cms} long hanging below it. When the coil was in action the tubes lighted up, but there was no trace of a node or a ventral segment.

* A. Lindemann, Ann. der Physik, ii, p. 376, 1900.

† A. Slaby, Elektrotechnische Zeitschrift, 1902, p. 168; extended abstract in Lond. Electrician, vol. xlix, p. 6, 1902.

‡ F. Braun, Phys. Zeitschrift, iii, p. 143, 1900.

Inductive Method of Excitation (Braun, Marconi).

The experimental disposition used for inductively exciting the oscillations about the antenna is illustrated in fig. 4.

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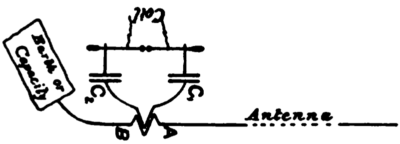

C_1, C_2 are two condensers. From the inner coatings conductors lead off and end in knobs, between which sparks are made to pass by an induction coil. The outer coatings are joined by a thick wire bent into a single turn which acts as the primary of a transformer. The secondary of this transformer, AB, consists of a few turns. To one end of it, A, the antenna is joined and to the other end, B, the earth, any desired capacity or a wire similar to the antenna.

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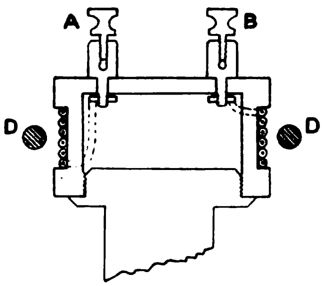

The apparatus actually used in the investigation was the transmitter of the experimental set supplied by the Gesellschaft für drahtlose Telegraphie, Berlin, Germany, of the system Prof. Braun and Siemens & Halske. Each condenser consisted of four small tubular jars, $17{\cdot}5^{mm}$ in diam., 2^{mm} thick and with coatings approximately $7{\cdot}5^{cms}$ high. The spark-gap was from 1 to 2^{mm} long, and no attention was paid to polishing the knobs. That portion of the condenser circuit forming the primary of the transformer was a single turn of copper wire 6^{mm} in diameter, bent into a circle of mean diameter $6{\cdot}8^{cms}$ (D, D, fig. 5). The secondary, which was within the primary, consisted of $5\frac{1}{2}$ turns of heavily insulated wire of a total length of 99^{cms}. The diameter of the wire and its insulation was $2{\cdot}5^{mm}$, and the turns lay close together. A vertical section, one-half of full size, is shown in fig. 5.

As is known, in this system earth connection is usually not made,* but in place of it an earth plate is used, intended to balance the antenna and thus give symmetry to the oscillating system. The earth plate supplied with the apparatus was a hollow metal cylinder, 20cms long and 8cms in diameter. It was joined to a binding post, B, of the transformer secondary by a wire 40cms long. When it was desired to join B to earth the cylinder was securely bound to a large metal plate, which, along with other metal sheets, was connected to the heating-radiator. When employing a wire similar to the antenna to balance it, this wire was joined to B and, as in the experiments described above, was drawn up towards the ceiling.

In supplying the apparatus the makers stated that it was designed to emit waves of length 10 meters. It was very constant in its action and easy to handle.

An extended series of observations was made with antennæ varying from 200 to 1000cms, and with four different attachments to the end B of the transmitter transformer, as follows:

A. With cylinder joined by a wire 40cms long.
B. With earth joined to this cylinder.
C. With a wire similar to the antenna joined to B.
D. With the end B free.

A view of the results obtained is given in Table II, and figs. 6, 7, 8, 9.

TABLE II.

Inductive Method.

Length of antenna. cms.	Distance, in cms., of minima from free end of wire.			
	A. With cylinder capacity.	B. With earth connection.	C. With equal wire.	D. With end free.
200	....	....	....	140
225	184	190	(70), (190). None	....
250	200	180	(90). None	....
300	[238]	187	[225]	148
400	187, (265)	185	185	160, (280 ?)
500	180	180	180	183
600	186, (375), (520)	200, (520)	182	167, (415)
700	188, (637)	200	180	148, 617
800	191, (745)	200	189	....
900	200, (790)	200, (380), (790)	193, (790)	....
1000	180, (320)	208, (800), (920)	180, (860)	....
Mean	188·4	193	184·1	
	Mean of 184·4, 193, 184·1 = 188·5cms.			

On examination it will be seen that the curves obtained by the three methods, A, B, C, are hardly distinguishable from

* See discussion on a paper by M. Wien, read before the 74. Versammlung deutscher Naturforscher und Aerzte at Carlsbad, Sept., 1902.—Phys. Zeit., Oct., 1902.

each other. Those with method D differ from these somewhat.

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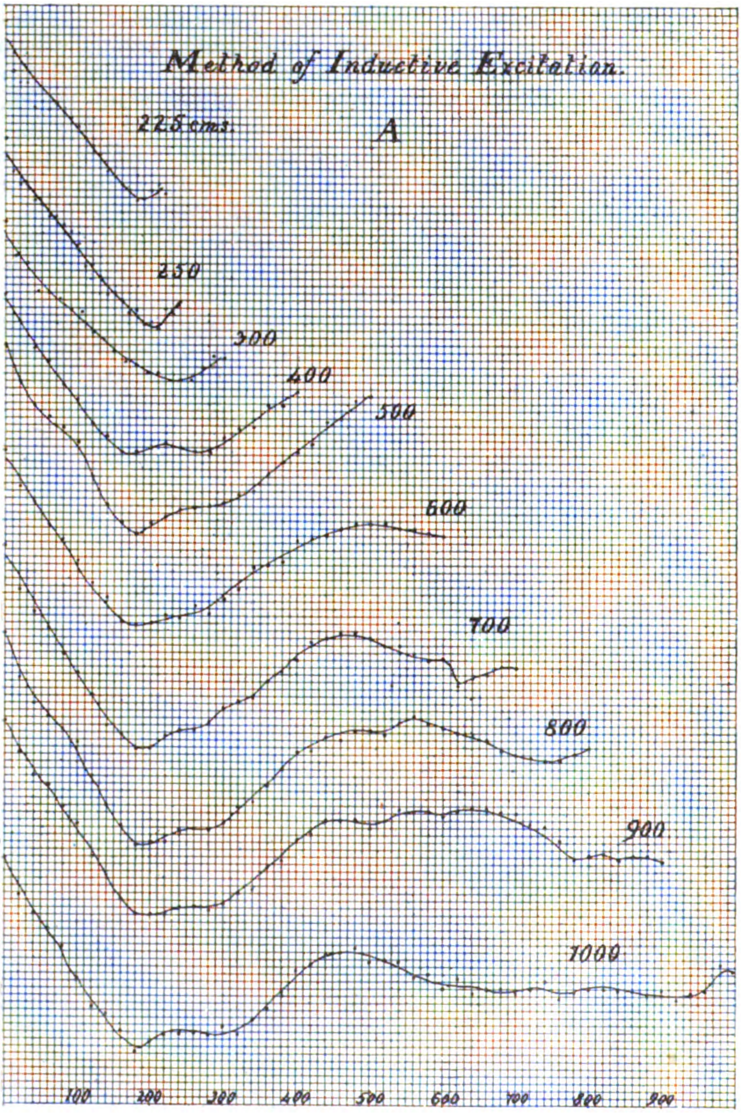

In A, B, C, there is a gradual fall from the free end to the other, which gives the fundamental of the wire itself; but

superposed on this and more prominent than it, is another oscillation very definitely formed as far as the first minimum. This is unquestionably due to the oscillation of the condenser

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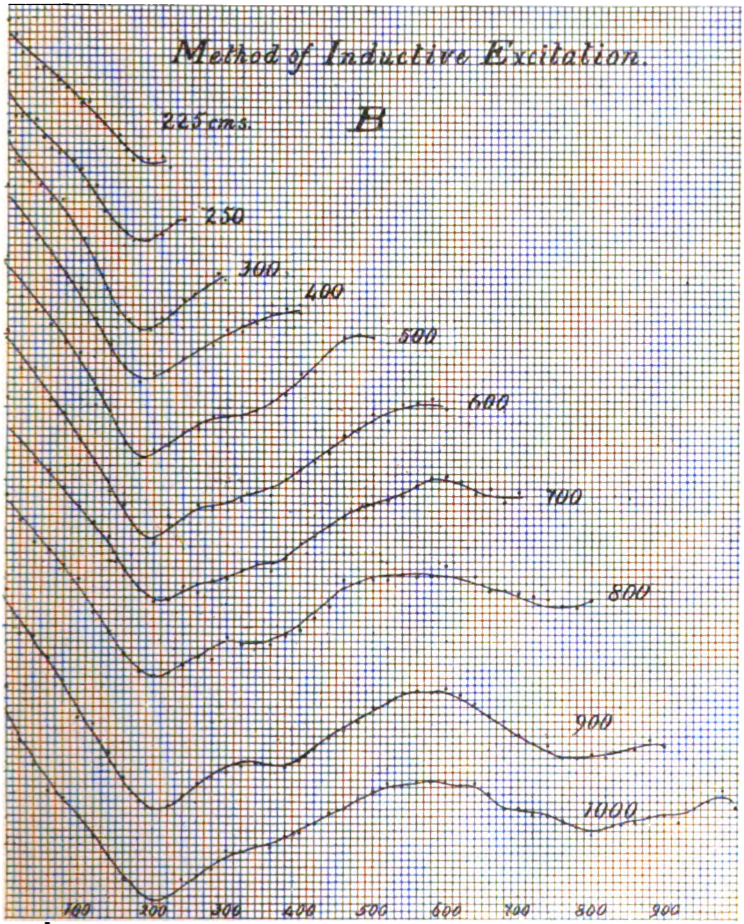

circuit, and the distance from the free end to the minimum is a quarter-wave-length of it.

With wires of lengths 225 and 250$^{\text{cms}}$ in disposition C, there is to be seen only the fundamental of the wire, while with length 300$^{\text{cms}}$ in dispositions A and C the minimum appears abnormally displaced. The curves in these last two

cases are not so smoothly formed and are not considered in the calculation of the means given in Table II. The mean of the

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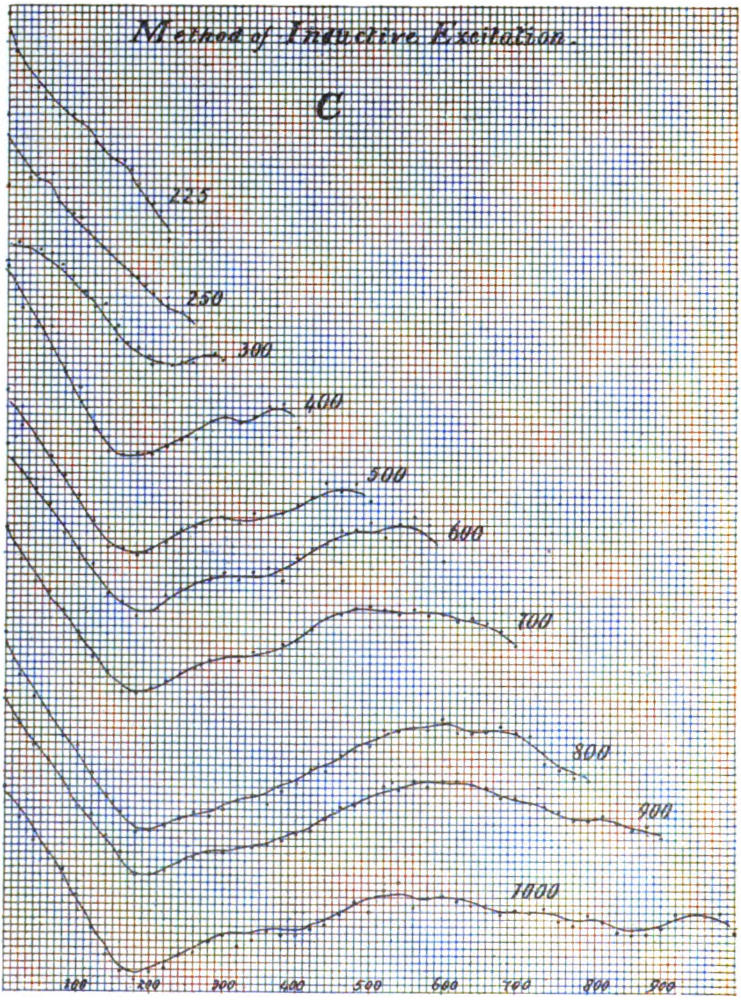

three means given in the Table is 188·5^{cms}, which I take to be quarter-wave-length of the condenser circuit oscillation.

The curves obtained with disposition D, shown in fig. 9, differ somewhat from the others. Here the variation of potential at the end joined to the transformer is almost as great as

that at the free end. This is due, without doubt, to the fact that the antenna and transformer secondary together compose a single conductor, and the fundamental oscillation would have a potential loop at each end. But the chief minimum shows a rather remarkable variation. As the length of the antenna

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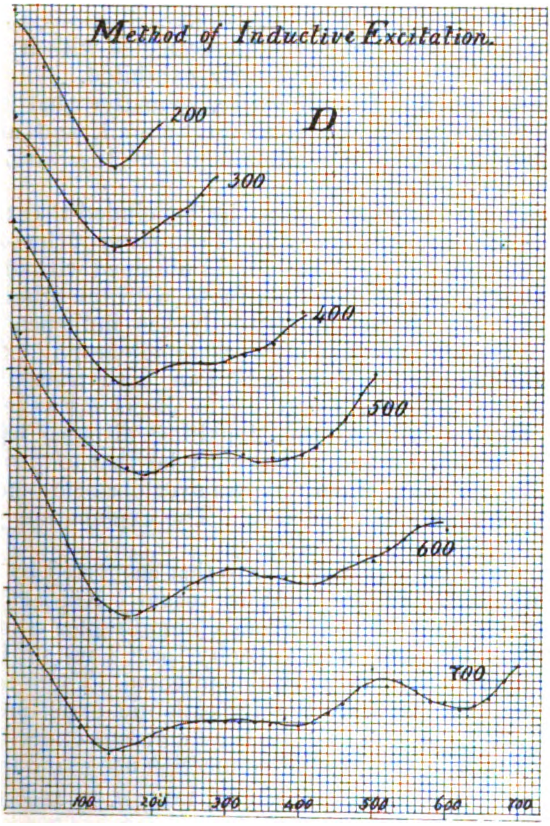

is increased the distance of the minimum from the free end increases until it reaches its greatest value with a wire 500^{cms} long, and then it decreases. The reason for this is not very evident, but it seems that in this disposition the reaction of the secondary of the transformer upon the primary varies with the length of the antenna joined to it, thus altering its frequency, the greatest change being when the wire is 500^{cms} long. With antenna of this length the readings were the highest of the

series, and the quarter-wave-length deduced from the curve approximately the same as that obtained in the dispositions A, B, C.

As has been already remarked, the curves are very clearly defined. The successive sets of readings agree remarkably well, but yet it was impossible to get a second mimimum at a distance of three-quarters of a wave-length from the end. This is not what was looked for with this transmitter. One would expect the condenser circuit, with its persistent oscillations, to keep up perfect standing waves in a wire in resonance with it, but with no length used was this satisfactorily exhibited.

The waves radiated from the wire, no matter what its length, have the frequency of the condenser circuit, and also, to a smaller degree, that of the fundamental of the wire. Overtones are scarcely noticeable.

From my experiments it must be concluded that the earth connection does not injuriously affect the *form* of the oscillation about the antenna; indeed, the curves obtained with disposition B are rather more uniform than those with the others. The earth connection, however, assuredly has influence in other ways. I believe all systems of wireless telegraphy except the Braun and the Lodge-Muirhead* join both transmitter and receiver to earth; and, according to Jackson,† severing the earth connection reduced the signalling distance by 85 per cent. The action of the earth must be that of *guiding* the waves, thus allowing them to pass over obstacles such as the bulging-out of the earth's surface. The explanation given by Taylor‡ seems the most satisfactory.

This explanation is very similar to that suggested by Lecher,§ and to that by Heaviside.‖ More recently Köpsel¶ has put forward the view that in Marconi's long-distance transmission the earthing wire and earth capacity form a system in partial if not in entire resonance with the antenna. There may have been some such effect in the transatlantic experiments, but such can hardly be the case in the numerous experiments by other workers who find ground connection necessary to success.

*See Nature, vol. lxviii, p. 247, July 16, 1903; N. Y. Electrical World and Engineer, vol. xlii, p. 173, Aug. 1903.

† H. B. Jackson, Proc. R. S., lxx, p. 254, 1902.

‡ J. E. Taylor, Lond. Electrical Review, May, 1899. See also L. de Forest, N. Y. Electrical World and Engineer, May 17, 1902; Prasch, Die drahtlose Telegraphie (Stuttgart, 1900). p. 65.

(See, however, a communication on Theories in Wireless Telegraphy in N. Y. El. W. & E., Oct. 31, 1903, by R. A. Fessenden.—Note added on correcting proof.)

§ E. Lecher, Phys. Zeitschrift, iii, p. 13, 1902; iv, p. 320, 1903.

‖ Heaviside, Electromagnetic Theory, i, § 60; ii, § 393. See preface to vol. ii.

¶ A. Köpsel, Dingler's Polytechnisches Journal, June, 1903; abstracted in N. Y. Electrical World and Engineer, Aug. 29, 1903.

Method of Direct Excitation (Slaby-Arco).

In the method of *directly exciting* the oscillations, one point of the condenser circuit is joined to the antenna, another point to earth.

A diagram of the connections is shown in fig. 10.* A and B are the terminal binding posts of the secondary of the induc-

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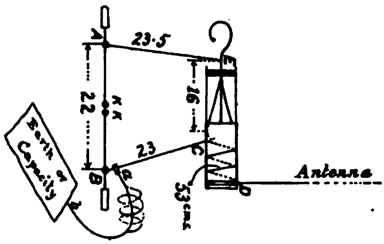

tion coil, the distance between them being 22^{cms}. The spark-knobs, K, K were $16{\cdot}5^{mm}$ in diameter and the spark-length was from 1 to 2^{mm}. The Leyden jar had a mean diameter of $5{\cdot}7^{cms}$, with walls about 4^{mm} thick. The coatings were 10^{cms} in height and of area about $180^{sq\ cms}$. The lengths of the various parts of the circuit are indicated on the figure, the entire condenser circuit having a length of approximately

$$53 + 23 + 22 + 23{\cdot}5 + 16 = 137{\cdot}5^{cms}.$$

The wire CD wrapped about the jar was heavily insulated and consisted of $2\frac{1}{2}$ turns. This corresponds to Slaby's "syntonizing coil," though, of course, it was not used for syntonization in my experiments. The turns were about 2^{cms} apart, so that its self-induction was practically the same as that of an equal length of straight wire. It was put in this form, however, through a desire to have the arrangement as nearly as possible like that used in actual practice.†

It will be seen that 75^{cms} of the closed condenser circuit are a part of the open antenna circuit. According to Braun,‡ the larger this portion of the condenser included in the antenna is, the better will be the effect, and it performs a rôle other than simply as a portion of the antenna.

Four different arrangements were employed to balance the antenna wire.

* The arrangement was taken from that described by the Allgemeine Elektricitäts Gesellschaft in their circular regarding the Slaby-Arco system, 1902. See also Boulanger et Ferrié, Télégraphie sans Fil, p. 156, 4th ed., 1902.

† Several good illustrations of the latest apparatus are given in C. Arldt, Die Funkentelegraphie, pages 48–51 (Leipzig, 1903).

‡ F. Braun, Ann. der Physik., viii, p. 199, 1902.

A. The cylinder capacity used in the experiments with the Braun transmitter was connected to the condenser circuit at *a*, the length of the wire *ab* being 40$^{\text{cms}}$. Thus the length from this capacity to the end D, of the antenna, was 40 + 75 = 115$^{\text{cms}}$.

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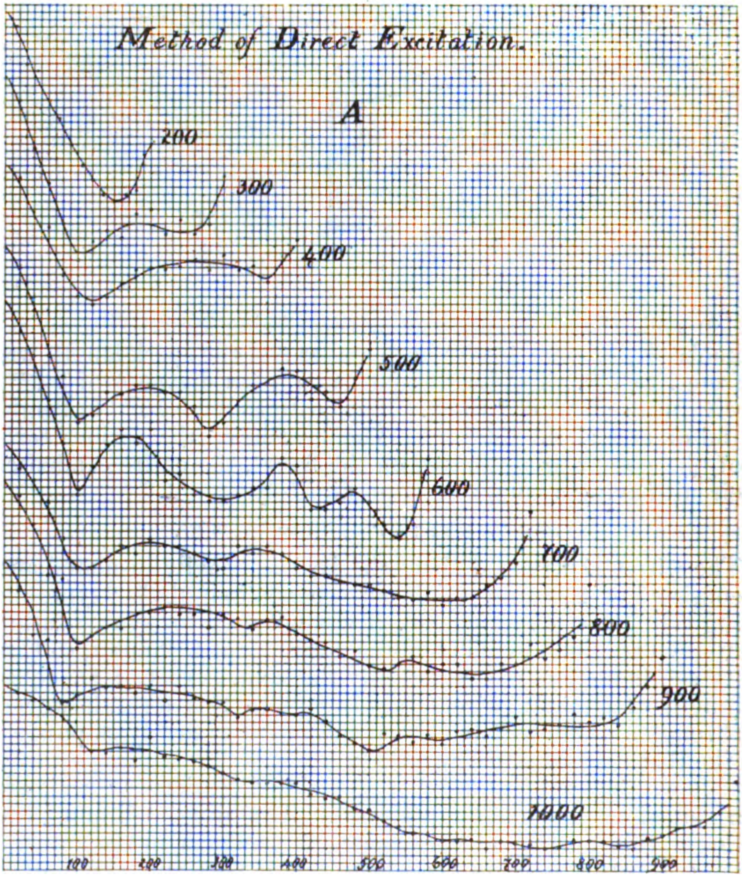

B. The point *a* was joined to earth (the same as above), the wire *ab* being 25$^{\text{cms}}$ long. In this case the length of the conductor between earth and D was 75 + 25 = 100$^{\text{cms}}$.

C. To *a* was attached a wire precisely similar to that used as antenna. Here the two wires were joined by 75$^{\text{cms}}$ of the condenser circuit. As before, the balancing wire was drawn up in a vertical direction towards the ceiling.

D. The same as B, except that between a and b an inductance coil was inserted. This coil was of heavily-insulated

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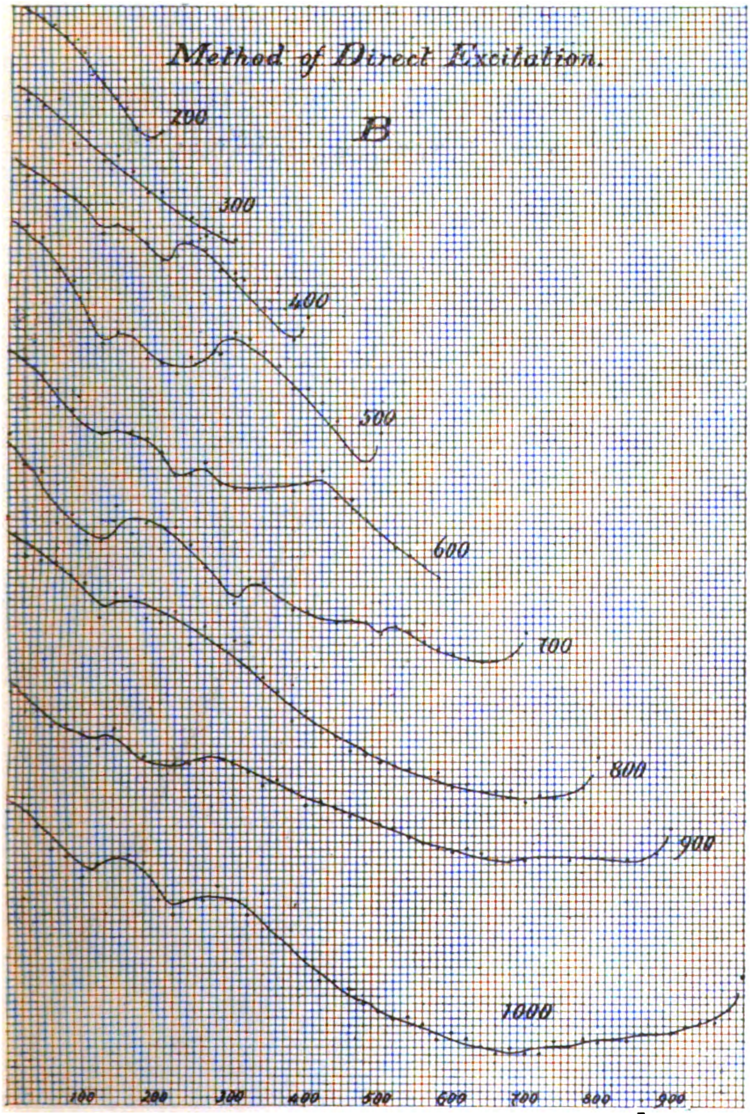
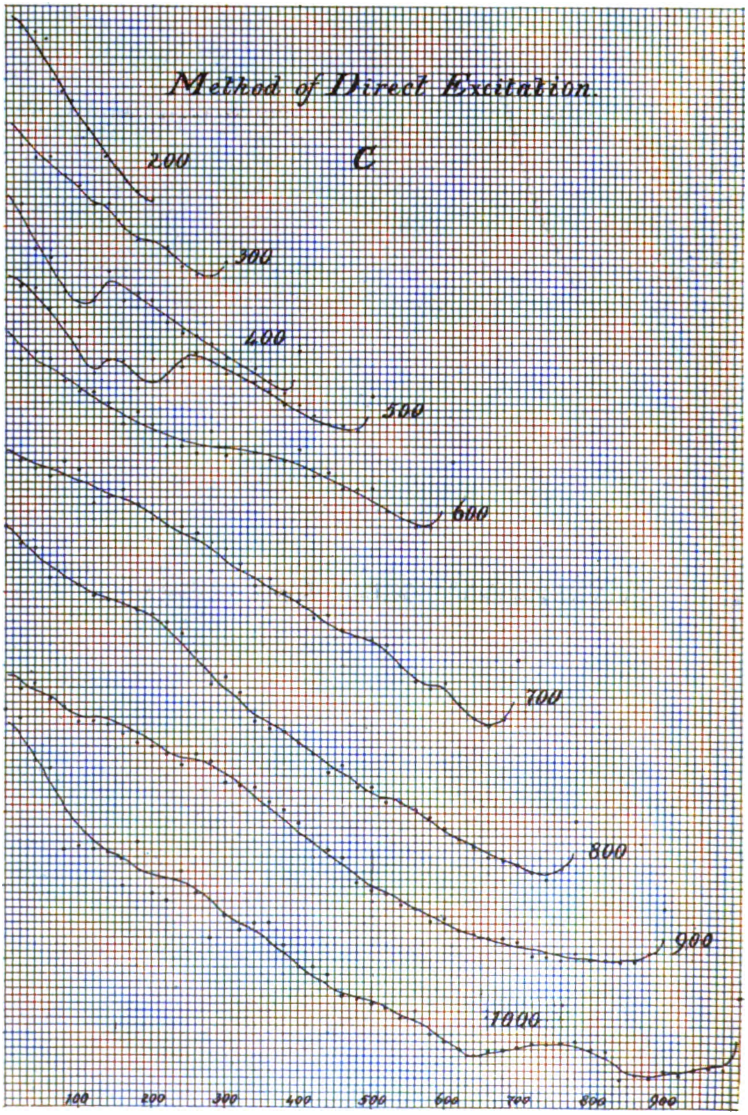


wire, the conductor having a diameter of 2^{mm}, the diameter over all being 7^{mm}. There were 4 turns lying close together,

with a total length of 82cms. The object was, of course, to see if there would be any evidence obtained of the wave-length

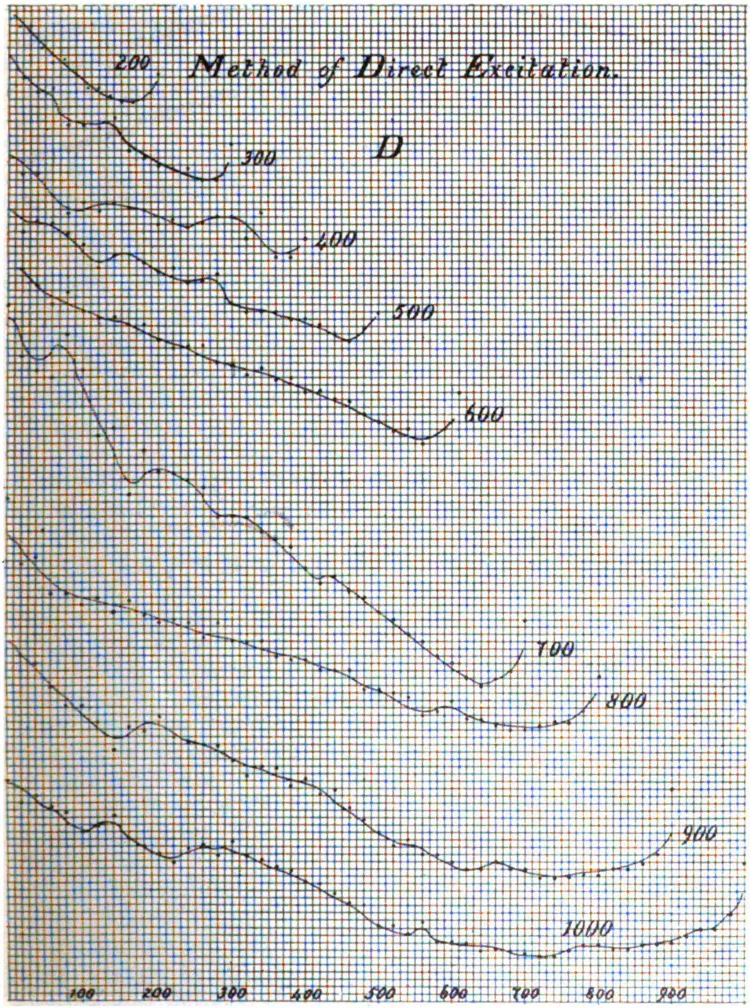
18



being increased by inserting this inductance coil at the base of the antenna. In this case the length of the conductor from D to earth was 75+82+25 = 182cms, though the inductance coil, itself, would probably be equivalent to 200cms of straight wire.

A view of the results obtained on using wires varying in length from 200 to 1000$^{cm.}$ and the four experimental dispositions just described is given in Table III and the curves of figs. 11, 12, 13, 14.

14



It is seen that the curves obtained with disposition A (fig. 11) are of a different type from those with the three other dispositions. In these latter there is always a gradual but decided drop of potential-variation from the free end of the wire, that is, the fundamental of the wire is very intense,

TABLE III.

Method of Direct Excitation.

Length of antenna. cms.	Distance, in cms., of minima from free end of wire.			
	A. With cylinder capacity.	B. With earth connection.	C. With equal wire.	D. Inductance spool and earth.
200	(60), 153	None	None	(60), 160
300	100	None	None	(90). None
400	120, 360	(120), (205). None	105. None	80, 230, 380
500	106, 280, 455	(120), 215	(125), 198	(120), (200), (320)
600	100, 290, (435), (545)	None	None	None
700	110, 300, (580)	100, 300, 500. None	(120). None	(58), (170), (280), (420). None
800	100, (300), (518), (650)	(120). None	None	None
900	90, 310, 495	(200). None	None	(140), (320), (740). None
1000	(160). None	(100), (220), (700 ?)	(100). None	(100), (220). None

though the curves show other oscillations superposed. With disposition A this strong fundamental is absent, and the minima present are undoubtedly due to the oscillations impressed on the wire by the condenser circuit. All through this series will be seen a minimum occurring at approximately 100^{cms} from the free end of the wire, and in many cases one or two other minima spaced at approximately 200^{cms} apart. The same minima appear in disposition B with wire 700^{cms} long, and C with wire 400^{cms}.

The mean value of the wave-length is 404^{cms}, calculated as follows:

	Wire		$\frac{\lambda}{2}$
A.	300	$2 \times 100 =$	200^{cms}
	400	$2 \times 120 =$	240^{cms}
		$360 - 120 =$	240^{cms}
	500	$2 \times 106 =$	212^{cms}
		$280 - 106 =$	174^{cms}
		$455 - 280 =$	175^{cms}
	600	$2 \times 100 =$	200^{cms}
		$290 - 100 =$	190^{cms}
	700	$2 \times 110 =$	220^{cms}
		$300 - 110 =$	190^{cms}
	800	$2 \times 100 =$	200^{cms}
	900	$2 \times 90 =$	180^{cms}
		$310 - 90 =$	220^{cms}
		$495 - 310 =$	185^{cms}
B.	700	$2 \times 100 =$	200^{cms}
		$300 - 100 =$	200^{cms}
		$500 - 300 =$	200^{cms}
C.	400	$2 \times 105 =$	210^{cms}
		Mean	202^{cms}

The curves in B and C (figs. 11, 12) are very similar, from which it is to be concluded that the simple earth connection is equivalent to a wire similar to the antenna, or, as already indicated in previous experiments, the earth acts as a mirror.

The curves in D (fig. 14) are not so regular in their form as those in B and C. There is a gradual fall of potential, but the fundamental is not so intense as in the others, and there is a superposition of other oscillations. This agrees with the statement of de Forest* that with this arrangement there is liability to overtones. It is to be observed, too, that here again the disturbance is produced at some distance from the earth end.

It is to be noted that none of the curves in A is similar to any in C. From this it follows that though as far as the *frequency* of the oscillations in an open circuit is concerned, a capacity may replace an inductance, still the *form* of the oscillations is quite different in the two cases.

Thus the direct method is in general result similar to the simple system, but it is more regular and more powerful. According to Wien† the radiation is 13 times as intense as that of the simple radiator.

III. *Conclusions.*

The following conclusions seem to follow from my experiments:

1. In the simple Marconi method and the method of direct excitation, when the antenna is joined to earth, the effect is similar to using a wire the same as the antenna to balance it; that is, considered from an optical point of view, the earth acts as a plane mirror.

2. In these conditions the chief oscillation is the fundamental of the antenna, with wave-length four times its length. The condenser circuit in the method of direct excitation impresses its wave-length on the antenna, but its oscillations are not nearly so intense as those proper to the antenna itself. Thus the manner of oscillation is essentially the same in the two methods, but the latter is more regular and powerful than the former.

3. In the inductive method of excitation, on the other hand, the prominent feature of the oscillations is that one due to the condenser circuit. With antennæ of different lengths there is little change in this oscillation, the curve indicating it being decided and definite; but only one quarter of its wave-length is shown. This may be due to the great losses from radiation by the wire. The fundamental proper to the antenna is also

* L. de Forest, N. Y. Electrical World and Engineer, May 17, 1902.
† M. Wien, Ann. der Physik, viii, p. 686, 1902.

present, but it is not nearly so intense as in either of the other two systems.

4. The most effective length of the antenna, therefore, is *one* quarter-wave-length, not a higher multiple.

5. When inductance is inserted between the condenser circuit and the earth the fundamental oscillation is not so regular or intense, other oscillations (overtones) being superposed.

6. For the production of oscillations by the direct method a small capacity cannot satisfactorily balance the antenna; in the inductive method, however, a capacity acts like an earth connection or a similar wire.

IV. *Continuation of Former Investigation.*

In the previous experiments with Hertzian plate oscillators of various sizes and with wires ranging in length from 300 to 860^{cms}, there was usually one "chief" minimum of potential-variation between 100 and 200^{cms} from the free end, and always a marked one about 10 or 15^{cms} from the other end of the wire. It was hoped that by employing longer wires the phenomena of standing waves would be much better exhibited, and that several "chief" minima would be shown. Such, however, has not proved to be the case. Wires 2050 and 4090^{cms} long were carefully explored, the action on the wire being produced by means of an oscillator having plates 40^{cms} square and the straight connection between 60^{cms} long, but the only unmistakable minimum was approximately 150^{cms} from the free end, the same as was perfectly formed with wires from 300^{cms} upwards.

Some evidence was obtained as to the cause of the marked minimum near the other end of the wire. It is due to the direct action of the oscillator on the detector. As described in the other paper, an attempt had been made to allow for this direct action by taking the reading when the wire was in place and also when it was removed, and then subtracting the latter from the former. This assumes that the two effects are quite independent, but such seems hardly to be the case. In the former experiments the detector lay in a horizontal plane on the top of a carriage which was moved along the wire. Thus the detector's length was parallel to that of the oscillator, though the little *wing* was perpendicular to it. As described in Part II of the present paper, the detector was now hung in a vertical plane from the wire, so that its length was perpendicular to the axis of the oscillator. With this arrangement the minimum disappeared, thus showing that it had been produced by the direct action of the oscillator on the detector.

University of Toronto, Toronto, Canada.

ART. II.—*Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. WORTMAN.

[Continued from vol. xvi, p. 368.]

SUBORDER ANTHROPOIDEA.

IN a previous part of the present work, I have given the characters by which this suborder is distinguished from the Cheiromyoidea and the Lemuroidea. I have likewise proposed and defined three divisions of the Anthropoidea, of which *Tarsius* and its allies constitute the first (Paleopithecini), the living marmosets the second (Arctopithecini), and the remaining higher Primates the third (Neopithecini). Of the twelve or more species of the Anthropoidea now known to occur in the Bridger, the organization of at least three can be determined with some degree of satisfaction from the material now at hand. This information is not limited to any one part, but includes nearly every portion of the skeletal structure. It is reasonably clear, therefore, that these three species are primitive members of the Neopithecine division of the Anthropoidea. In like manner, the skull of the Wasatch species—the so-called *Anaptomorphus homunculus*—is sufficiently complete and well preserved to show that it is a very near relative of the living East Indian *Tarsius*, and hence a member of the Paleopithecini. The remaining nine or more species from the Bridger are represented mostly by teeth alone, and it is therefore not an easy matter to decide correctly to which of the three groups these forms belong.

As regards the Arctopithecini, or the living marmosets, our knowledge is confined almost exclusively to the existing species. It has been already noted that some of their characters are unique among the Primates. Whether the lack of opposability of the pollex and hallux is to be looked upon as a degeneration from a former more perfect condition of prehensility of the extremities, or whether it represents a stage in the process of acquirement of the opposability of these digits, can not now be determined. It is worthy of note, however, that the internal cuneiform and the proximal end of the articulating metapodial resemble the corresponding parts of the lemurs and monkeys much more than those of any other animal; and, notwithstanding the lack of opposability, this likeness would be sufficiently close to indicate their ordinal position did we know the marmosets from their skeletons alone. There are at the same time some peculiarities in the make-up of these bones, which would lead the cautious anatomist to hesitate in pronouncing upon the opposability of the hallux, especially if

he were to take into consideration the clawed condition of all the digits. The habits of the marmosets, while as strictly and completely arboreal as in any of the Primates, resemble those of the squirrels more than those of the monkeys proper. According to Bates, who had excellent opportunities for observing them in their native forests, the Negro Tamarin (*Midas ursulus*) confines itself mostly to the larger branches, and is frequently seen passing up the perpendicular trunks, clinging to the bark with its claws in a manner not dissimilar to that of the squirrels. This method of climbing is doubtless true of all the marmosets, and the lack of opposability of the hallux and pollex is correlated with the possession of sharp compressed claws instead of flattened nails.

The tritubercular upper molars furnish another character of considerable importance in determining the relationship of the marmosets to the other groups. No Primate of the Eocene is known to possess fully quadritubercular molars. Some of the Adapidæ have a rudimental fourth cusp, but the crown can not be said to be as fully quadritubercular as that of the higher modern apes. By far the greater number of the species have simple tritubercular upper molars, and with the exception of the marmosets and *Tarsius* all the modern representatives of the Anthropoidea have four fully developed cusps. It follows, therefore, that these two groups are survivals from this early condition of the tritubercular stage of development of the molars, and that their detachment from the main axis could not have taken place later than the Eocene. The loss of the last molar in the marmosets, while unusual for a Primate, has clearly taken place since that time, as in the Eocene all the known species have three fully developed molars. There is still another feature of importance exhibited by certain of the marmosets, which is worthy of notice. Forsyth Major found that, out of nineteen skulls of *Hapale* examined, in six the lachrymal extends beyond the orbit to such an extent as to join the nasal and exclude contact between the maxillary and frontal.* This is also true of two skulls of this genus in the Peabody Museum, and I am satisfied that this more primitive condition of the lachrymal is by no means of infrequent occurrence among these species of marmosets. These features are associated with a characteristic lack of depth of the lower jaw, a subglobular form of the condyles, and small size of the lower canines, which do not exceed the incisors, all of which constitute so many steps in the approximation to certain of the Paleopithecine apes of the Eocene. Upon the whole, I am fully persuaded that the ancestors of the marmosets must be sought for among the members of this latter group, and that

* Proc. Zool. Soc. London, Feb. 19, 1901, p. 146.

they had not departed very widely from the parent stock at the close of the Eocene. One of the earliest recognizable characters in the dentition by which they can be distinguished will undoubtedly be found in the reduction in the last molar. It is doubtful, moreover, whether in the history of this phylum the hallux and pollex have ever been opposable.

Section Paleopithecini.

Tarsius spectrum is the only living member of this group, and on this account its skeletal organization has an unusual interest for the paleontologist. In many particulars it still retains the generalized features which characterized its Eocene ancestors, while in others it has added some structural modifications, due doubtless to adaptation to slightly different modes of life. These characters relate to the loss of one pair of lower incisors, the development of a bony partition between the orbital and temporal fossæ, the reduction of the fibula and its coössification with the tibia, the grooving and broadening of the astragalus, and lastly the great elongation of the calcaneum and navicular. These modifications of the hind limbs are evidently in relation with, and the result of, saltatory habits, since *Tarsius* in common with all the lemurs having elongate tarsals is a powerful leaper.

The arboreal habits of the Primates have prevented in large measure the development of any great cursorial powers on the part of any of the species, but the habit of leaping from branch to branch has proved of manifest advantage to some of them in the capture of their prey, for in a number of the living species of lemurs this habit is almost as pronounced and highly developed as in certain groups of the Rodentia, the kangaroos, and others. According to Mr. Bartlett, late Superintendent of the London Zoological Gardens, Garnett's Galago is an especially active leaper. In speaking of this species, in a letter to Duncan quoted in Cassell's Natural History, Vol. I, p. 215, he says: "The other night I took an opportunity of letting one of these interesting creatures—Garnett's Galago—have his liberty in my room, and I assure you I was well repaid by his performance. Judge my utter astonishment to see him on the floor, jumping about *upright* like a Kangaroo, only with much greater speed and intelligence. The little one sprung from the ground on to the legs of tables, arms of chairs, and indeed on to any piece of furniture in the room; in fact, he was more like a sprite that the best pantomimist I ever saw. What surprised me most was his entire want of fear of Dogs and Cats. These he boldly met and jumped on at once, and in the most playful manner hugged and tumbled about with them, rolling over

and over, hanging on their tails, licking them on the head and face. I must add, however, that now and again he gave them a sharp bite, and then bounded off, full of fun at the noise they made in consequence of the sly nip he had inflicted. This active trickery he never appeared to tire of; and I was myself so pleased on witnessing the droll antics of the creature that the night passed and it was near daybreak before I put a stop to his frolics by catching and consigning him to his cage. In bounding about on the level ground, his jumps, on the hind-legs only, are very astonishing, at least several feet at a spring, and with a rapidity that requires the utmost attention to follow. From the back of a chair he sprang, with the greatest ease, on to the table, four feet distance."

The other species of *Galago*, as well as those of the Madagascar *Cheirogaleus*, also exhibit much activity, and have the power of leaping great distances in proportion to their generally diminutive size. Duncan says of the Senegal Galago (*Galago senegalensis*):* "It pursues Beetles, Sphinges, and Moths with great ardour, even while they are on the wing, making prodigious bounds at them, and often leaping right upwards to seize them. Should it by chance miss its object and accidentally fall from the branch to the ground, it re-ascends with the rapidity of flight to renew the hunt."

Tarsius is also a powerful leaper for so small an animal, and although not larger than a small common squirrel is said to make prodigious springs, both in the branches of the trees and on the ground, in pursuit of its prey.

Among many other groups of Mammalia, the leaping habit is by no means uncommon, and as a result important structural changes in the limbs are to be met with. In all such cases, however, if any modification of the hind limbs takes place in response to this mode of progression, it is almost without exception the metatarsus alone that is affected. Thus, among those forms of Rodentia in which the saltatory habit is most highly developed, as the Jerboas, the Cape Jumping Hare, and others, the metatarsals are greatly elongated and modified. The same is true of the characteristic leapers among the marsupials, as exemplified by the kangaroos and their allies. The development of this habit in certain of the Primates, however, has affected, not the metatarsals, but the tarsals, and the elongation is found in the calcaneum and navicular. This arrangement is unique among the Mammalia, and occurs in no other group of the Vertebrata except the Batrachia, notably the tree-frogs, as was long ago pointed out by Huxley.†

The cause for this modification of the tarsal bones to the

* Loc. cit., p. 238.
† The Anatomy of Vertebrated Animals, 1872, p. 389.

exclusion of the metatarsals is not certain, but it is in all probability in some way associated with the retention of the opposable hallux in the development of the elongated pes. It is of interest to note just here that the fourth digit of all those Primates with elongated tarsals is very perceptibly the longest and strongest of the series, more so, in fact, than in those species in which the tarsals are not elongated. It is all but certain that if this modification were to continue in an exclusively terrestrial habitat long enough to cause the opposable hallux to disappear, the fourth digit would become enlarged and modified, as in the kangaroos and their allies. The chief differences would, of course, be in the elements elongated. The shifting of the axis to the outside and the specialization of the fourth digit are the strongest possible proof that the foot of the kangaroo has been derived from an ancestral type in which the hallux was fully opposable, and hence indicating an arboreal habitat for its possessor. *Tarsius* is the most highly modified of all the Primates with respect to the elongation of the tarsals, as is shown by the reduction in size and the coössification of the fibula with the tibia, as well as in the grooving and broadening of the astragalus. It is in this species that the preponderance in the length and strength of the fourth digit over its fellows is greatest.

Of the known representatives of Eocene Primates in North America, there are no less than six or seven genera, including at least twelve species, which are more or less closely related to *Tarsius*. The skull is known in two of these species only, the remainder being represented by teeth and jaws exclusively. On account of the incompleteness of many of these remains it is quite impossible to determine whether they are members of the Paleopithecini or Neopithecini. It will require a knowledge of the relations of the lachrymal, as well as of the structure of the limbs, before these points can be finally determined. That they do not belong in the Lemuroidea is shown by the characters of the lower incisors and canines, which are known in all the species with the exception of one or two. As a mere matter of convenience in grouping, I arrange a number of these species temporarily in the Paleopithecini. In so doing, however, I wish to state distinctly that there are very good reasons for regarding some of them, at least, as true monkeys, directly ancestral to certain of the living South American forms. This will be further discussed under the descriptions of the species.

The divisions of these species of Primates into family and subfamily groups is in the present state of our knowledge attended with much difficulty. In one series including the genera *Omomys*, *Hemiacodon*, and probably *Euryacodon* also,

there are nine teeth in the lower jaw, which with little doubt are to be interpreted as two incisors, one canine, three premolars, and three molars. In another series which includes *Anaptomorphus*, *Washakius*, *Necrolemur*, and presumably *Microchœrus*, there are only eight teeth in the lower jaw, as in *Tarsius*. In this latter genus, the missing tooth is known to be an incisor, and it is almost equally certain that in *Anaptomorphus* it is a premolar. In *Necrolemur*, although perfect lower jaws bearing the full inferior dentition are known, it is quite impossible correctly to assign the teeth in the front of the jaw to their proper categories. In the case of *Washakius*, if the total number of teeth is correctly determined to be eight in each lower jaw, then it is reasonably certain that the missing tooth is an incisor, as in *Tarsius*. Just what significance is to be attached to those differences can not now be properly estimated, but if among the living Lemuroidea the presence or absence of one tooth does not indicate more than a subfamily distinction, I fail to see why such a character should be regarded as of greater importance among the extinct forms. It has been customary with some authors to associate *Microchœrus* and *Necrolemur* in a separate family, and remove them from the American species, on account of the complexity and more advanced character of their teeth. It has, in fact, been insisted upon by Leche* that they belong to the Lemuroidea. If, however, the carotid circulation is like that of *Tarsius*, they, with the American forms, probably belong in the Paleopithecini; and the complexity of their teeth will no more entitle them to distinct family rank than that of the Indrisinæ would cause them to be classified as a separate family of the Lemuroidea. The differences in tooth structure between *Necrolemur* and *Hemiacodon* are not as great as they are between *Propithecus* and *Lemur*.† I therefore provisionally arrange these extinct forms in a single family Anaptomorphidæ, with at least two well-marked subfamily divisions. There can be no doubt apparently that *Tarsius*, by reason of the modification of its hind limbs and because of other modernized features, should be placed in a distinct family.

* Untersuchungen ueber das Zahnsystem lebender und fossiler Halbaffen. Festschrift für Carl Gegenbaur, Leipzig, 1896.

† That *Necrolemur* and *Microchœrus* exhibit some striking resemblances to the Indrisinæ among the Lemuroidea, however, is certain, and it may well be that in these forms we have the ancestors of this group of lemurs and a true transition from the more or less upright position of the lower incisors to that of the procumbent implantation.

Family Anaptomorphidæ.

The family is divisible into two subfamilies, as follows:

Nine teeth in the lower jaw. Omomyinæ.
Eight teeth in the lower jaw. Anaptomorphinæ.

Subfamily Omomyinæ.

The genera of this subfamily are distinguished by the following characters:

Lower molars having three cusps on trigon, the anterior cusp of the last molar not being as distinct as that of the others; heel of last molar with three cusps; first and second molars narrow in front, with wider heel; last molar slightly smaller than first and second, with heel very little wider than trigon; fourth lower premolar with small internal cusp and an indistinct heel; third lower premolar without internal cusp or heel, but having a pointed crown whose summit rises above the crowns of the other teeth; canine larger than incisors or second premolar; neither first nor second incisor enlarged; superior molars tritubercular, with rounded external angles, and but moderately extended transversely; intermediates faint or absent; a rudimental postero-internal cusp present on first, less distinct on second, and absent on third molar; first and second molars subequal, third slightly smaller. *Omomys.*

Lower molars having three cusps on trigon, the anterior of the third being least distinct; heel of last molar with three cusps; first and second molars narrow in front, with broader heel; last molar longer but narrower than first and second, with heel very little wider than trigon; fourth inferior premolar with strong internal cusp and distinct heel; third premolar with rudimental internal cusp and heel; summit of crown not high and pointed as in *Omomys;* second premolar, canine, and external incisor small and of equal size; first incisor enlarged; superior molars tritubercular, with squarish outline externally, and with intermediates very distinct; a small distinct postero-internal cusp on first and second molars, but absent on third; a strong cingulum continued around inside of crown, and developing an additional cusp at the antero-external angle of the crown. *Hemiacodon.*

Lower molars having three cusps on trigon, the anterior cusp of the last molar being absent; heel of last molar without distinct internal cusp; first and second molars without much disparity in width between trigon and heel; last molar narrow and reduced; premolars, incisors, and canines unknown; superior molars tritubercular, with rounded external angles; intermediates small, but distinct; a postero-internal cusp on crown of second molar; cingulum continued around in front, developing a small cusp internal to the main internal cusp; last molar considerably reduced. *Euryacodon.*

Omomys Carteri Leidy.

Omomys Carteri Leidy, Proc. Acad. Nat. Sci. Phila., April, 1869, and Extinct Fauna of Dakota and Nebraska, 1869, p. 408, pl. xxix, figs. 13, 14; *Hemiacodon nanus* Marsh, this Journal, August 13, 1872, p. 213; *Palæacodon vagus* Marsh, this Journal, September, 1872, p. 224.

The type of this genus and species consists of a right mandibular ramus containing the third and fourth premolars and the first and second molars, together with the alveoli of all the remaining teeth of one side of the jaw. The specimen was found by the late Dr. J. Van A. Carter, near Grizzly Buttes, in the Bridger Basin, and is preserved in the collection of the Philadelphia Academy. A comparison of the type of *Hemiacodon nanus* with Leidy's very excellent figure, as well as with Osborn's outline drawing from a photograph of the type of *Omomys Carteri*, renders it perfectly clear that the two are not only generically but specifically identical. Another type which in all probability belongs to this species is *Palæacodon vagus*. This latter consists of three superior molars of the right side in perfect condition. In no specimen of the fifty or more individuals of *Omomys Carteri* contained in the Marsh collection are there upper and lower teeth in association, and I base my opinion that these superior molars of *Palæacodon vagus* are the upper teeth of *O. Carteri* upon the following considerations: In a closely allied species of the same genus, *O. pucillus*, in my own collection, there are upper and lower teeth which were found together in such a way as to render it reasonably certain that they belong to the same individual; there is a decided resemblance between the structure of the corresponding teeth of the two forms; in size the teeth of *P. vagus* correspond almost exactly with what the upper teeth of *O. Carteri* should be, as indicated by the relative measurements of the upper and lower teeth of *Hemiacodon gracilis*, *Tarsius spectrum*, and *Anaptomorphus homunculus*, in all of which the upper teeth are known; they do not agree in size with the lower teeth of any other known species of Bridger Primate. I therefore conclude that the type of *Palæacodon vagus* refers to the upper teeth of *Omomys Carteri*.

Description of the Type of Hemiacodon nanus.

The specimen upon which Professor Marsh established this species consists of a fragment of a right mandibular ramus, figure 120, containing the fourth premolar and all three molars in perfect preservation. The crown of the fourth premolar when seen from above has a somewhat squarish outline, slightly wider behind than in front, and is composed of a main central pointed cusp which arises a little above the level of the cusps of the molars. Upon the outside this cusp is convex, and internally

somewhat concave. A sharp ridge descends from the apex of the main cusp in front, curving gently inward to terminate at the base of the crown in a small, though distinct, anterior cusp developed from the cingulum. Posteriorly the principal cusp is flattened in such a manner as to present a triangular face looking upward and backward. Upon the descending ridge forming the inner border of this triangular area is a small, but distinct, internal cusp, which stands internal and posterior to the main cusp. The posterior face of the crown descends steeply to an indistinct ledge at the base, which is the rudiment of the heel. There are no additional cusps developed, however, in this situation, and the heel may be said to be practically rudimental or absent. It is a matter of importance to note the relations of the cusps, since they serve to explain the structure of the succeeding molars. There is a slight cingulum surrounding the base of the crown in front.

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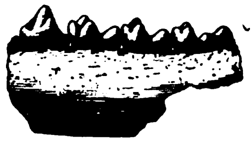


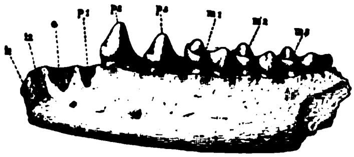
Figure 120.—Fragment of a right lower jaw of *Omomys Carteri* Leidy (type of *Hemiacodon nanus* Marsh); inside view; two and one-half times natural size.

The first and second molars are of nearly equal size, and like those of so many other primitive Primates their crowns are composed of an anterior, narrow, triangular portion bearing three cusps—the trigon, and a broader posterior basin-shaped moiety—the heel. The trigon of the first molar is most distinct, and the three subequal cusps are arranged in the form of an equilateral triangle. If the external cusp is taken as the apex, the base coincides almost exactly with the tooth line. It results from this arrangement that the internal cusp is situated posterior and internal to the external cusp, which corresponds to, and is strictly homologous with, the main cusp of the premolar in advance. The anterior cusp of the trigon is well developed, of a distinctly conical form, and projects slightly forward in advance of the crown. The heel broadens rapidly, and is composed of a large V-shaped external, and a smaller, more or less conical, internal cusp, inclosing a depression or valley. This valley is completed behind by two ridges passing inward and backward from the two cusps of the heel. At the angular point where these two arms meet, a slight swelling of the enamel occurs, which may be spoken of as an additional cusp.

The second molar differs but little from the first, the only noticeable variation being that the anterior cusp of the trigon is considerably smaller, less conical, and occupies a more posterior position. The external and internal cusps of the trigon are likewise more nearly opposite each other, or transverse to the long axis of the jaw.

The third molar differs from the two in advance of it in showing a still further reduction of the anterior cusp of the trigon, which can hardly be said to be distinct, as well as the presence of a well-developed third cusp and a more elongated

121



122

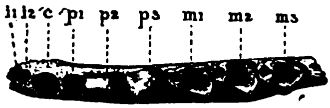


FIGURE 121.—Left lower jaw of *Omomys Carteri* Leidy; showing the alveoli for front teeth; external view; two and one-half times natural size; drawn from two specimens.

FIGURE 122.—Crown view of the preceding figure; two and one-half times natural size.

heel. It is also noticeably narrower, and in many respects distinctly smaller, than the anterior molars. The heel has a large submedian cusp, which stands a little nearer to the inner than to the outer side of the crown.

From the great number of additional specimens of this species in the collection, it is possible to learn the exact dental formula of the lower jaw, which is shown in the accompany-

123

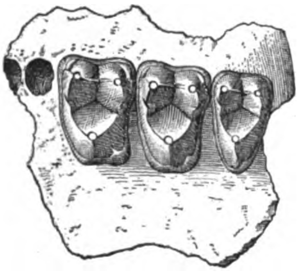


FIGURE 123.—Crown view of three superior molars of *Omomys Carteri* Leidy (type of *Palæacodon vagus* Marsh); four times natural size. The cingular cuspule internal to the main antero-internal cusp of the first molar is worn away in the specimen, and has not been indicated by the artist with sufficient distinctness. The external cusps are more flattened externally than is shown in the drawing.

ing cuts, figures 121 and 122. There is no specimen in which the crowns of the incisors, canines, or first (second) premolar are preserved, but that of the second (third) is shown in several examples. Its chief characters are as follows:

There is a single high pointed cusp, which rises considerably above the remaining teeth; there is no internal nor ante-

rior cusp; the heel is little developed, and there is a faint indication of a cingulum in front.

The premolar in advance of this, which is really the second according to the proper enumeration, has a single fang distinctly smaller than that of the canine. The two incisors, as determined by their alveoli, were also smaller than the canine, and had an erect position as in the monkeys, not procumbent as in the lemurs. In one specimen, the first is shown to be a little larger than the second, as in some monkeys. The mandibular rami were never coössified.

Description of the Type of Palæacodon vagus.

Of the upper teeth, the molars, figure 123, alone are known, if my determination that those of *P. vagus* refer to *Omomys Carteri* is correct. From what has just been said, I think there can be little doubt of this. The first molar is the largest of the series, and its more or less rectangular crown is made up of three principal cusps arranged in the form of a triangle, of which two are external and one is internal. The external cusps are imperfectly conical, slightly flattened on the outside, and connected with the internal by two distinct ridges (the trigonal ridges), upon which near the middle are developed two small, indistinct, intermediate cusps. The large internal cusp is imperfectly V-shaped, and around the inner side of its base there is a strong cingulum. Posterior and internal to this cusp, the cingulum develops a considerable swelling, which is the beginning of the posterior internal cusp of the higher monkeys. It is built out in such a way as to give a decidedly rectangular appearance to this part of the outline of the crown. This aspect is augmented by the unusual development of the cingulum at the antero-internal angle, where it likewise develops a small, though distinct cusp. In the second molar, which is slightly smaller than the first, the structure of the crown, as well as the arrangement of the cusps, is essentially the same. The postero-internal cusp is, however, not so well developed, and the internal outline of the crown is more rounded and less angular than that of the first molar. The last upper molar is reduced to about the same degree as that of the lower jaw. The intermediates of this tooth are very indistinct, and the internal cingulum is little developed. The inner part of the crown is narrower and more pointed.

The premolars are unknown, but in the type specimen the fangs of the fourth are to be seen. These consist of two external and one internal, as in the molars. Of the two external roots, the posterior seems to be the smaller.

The vertical range of this species is great, and specimens occur from the lowest to the highest levels of the beds.

[To be continued.]

Art. III.—*The Initial Stages of the Spine on Pelée;* by T. A. Jaggar, Jr., Cambridge, Mass.

Dr. Hovey's interesting studies* of the remarkable spine which has been developed on the summit of the new cone of débris on Mt. Pelée, in Martinique, recall to the writer certain notes and photographs made soon after the first eruption in 1902. These notes are of some interest in the light of Hovey's discoveries, and they are presented here as representing what is perhaps the first record made in the field of the process of spine-growth. A theory of origin for such spines was crudely framed at the time, but many details were obscure. Hovey's article has cleared up some of these points, and an explanation of the phenomenon is here suggested, partly at variance with the theory of the French geologists.†

The First Observed Spine.

On May 21, 1902, the most distinctive features of the inner cone were its low relief relative to the walls of the gorge, and the materials of which it was composed. It appeared to be a heap of scaly or crusty bowlders, "smouldering" in appearance, brown dust clouds rising from the crevices between the fragments. The cone had a rounded crest and its height above its apparent base was not more than 400 feet. The old rim of the basin at the head of the Rivière Blanche rose above it; the diameter of this basin appeared to be about 800 feet.

On June 27th, 1902, from Carbet, the cone was seen to have grown to a height somewhat above the rim of the gorge. The mountain at that time was almost continuously capped with a rain-cloud; for a few minutes that afternoon, however, it partially cleared, and the detail of the cone's slope was seen with a Zeiss binocular to consist of large fragments of brownish angular material resting on a bed of apparently finer gravel. The reddish dust 'cauliflowers' accumulated about every half-hour and rolled down the gorge of the Rivière Blanche from the cone. Sometimes this phenomenon was followed by a low rumbling roar. This suggested that avalanches of loose rock and gravel were falling, either from the rim of the crater or the slopes of the cone. The basin had certainly caved in more or less since May 21st, for it was much wider, and the cone had gained enormously in both height and breadth. From the Carbet beach, at night, a bright incandescent streak was seen

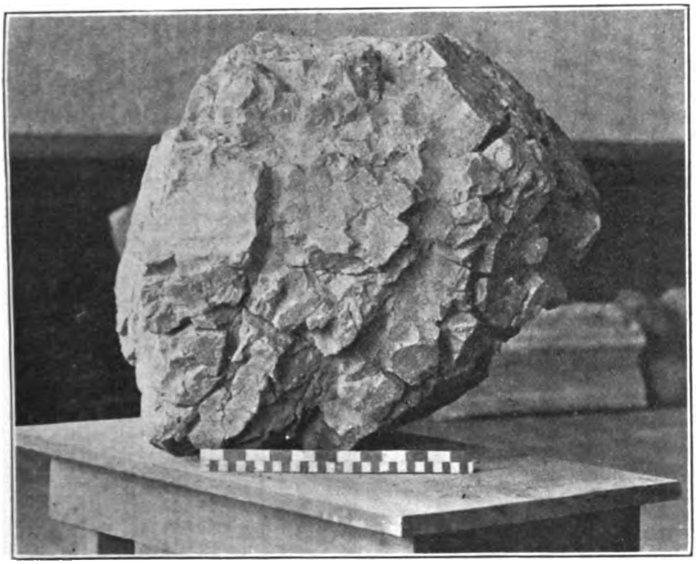
* E. O. Hovey, The New Cone of Mont Pelé and the Gorge of the Rivière Blanche, Martinique. This Journal, October, 1903, p. 269.

† Hovey, loc. cit. p. 276. Lacroix, Comptes Rendus, Oct. 27 and Dec. 1, 1902.

crossing the west side of the base of the cone obliquely from south to north *upwards*. The glow increased and diminished visibly, and on one occasion a sudden increase was followed by a rumbling sound.

Mention has been made of the scaly appearance of the fragments on the slope of the cone. They appeared quite similar to the "bread-crust" bomb from Pelée figured in the accompanying photograph (fig. 1). This bomb has the specific

1

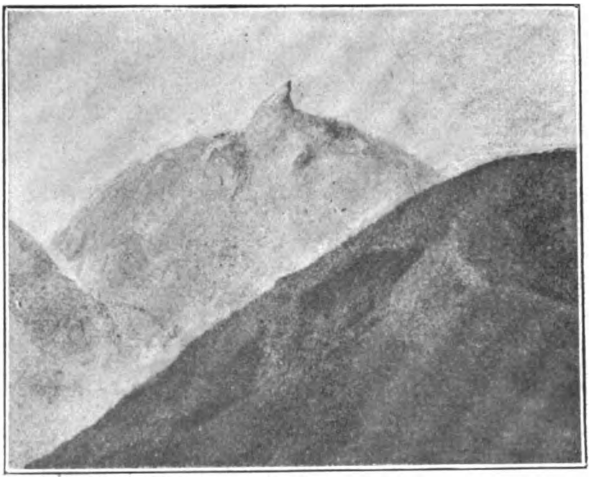


Bomb from Mt. Pelée.
(Scales shown are inches and centimeters.)

gravity of andesite, shows a brecciated composition, is semi-vitreous on the outer surfaces, and is uniformly cracked in deep gashes (4 inches). This structure seems to indicate that the outer portion of the block has been plastic, while the interior remained a solid rock. Other similar fragments, less deeply fissured, may be found on the slopes of Pelée and Soufrière, and these are not hardened spheres of molten lava, but angular pieces of old volcanic rocks. The presence of pumice among the products of Pelée's eruptions does not of necessity imply a new lava; much of the ancient material is pumiceous. These bread-crust bombs, however, are not made of pumice, but consist of hard crystalline andesite, frequently containing inclusions.

On July 6th, 1902, at 7 A. M., the writer had the good fortune to see the whole cone clear of clouds for about ten minutes. The viewpoint was St. Pierre, and others of the party were E. C. Rost, photographer, E. Lavénaire of the Government office of Martinique, and L. Weisberg, correspondent of the New York Sun. Photographs were secured by Mr. Rost, in sequence, showing the successive stages of development of the cloud-cap on the crater. One of these photographs is here reproduced, showing the volcano at the moment

2



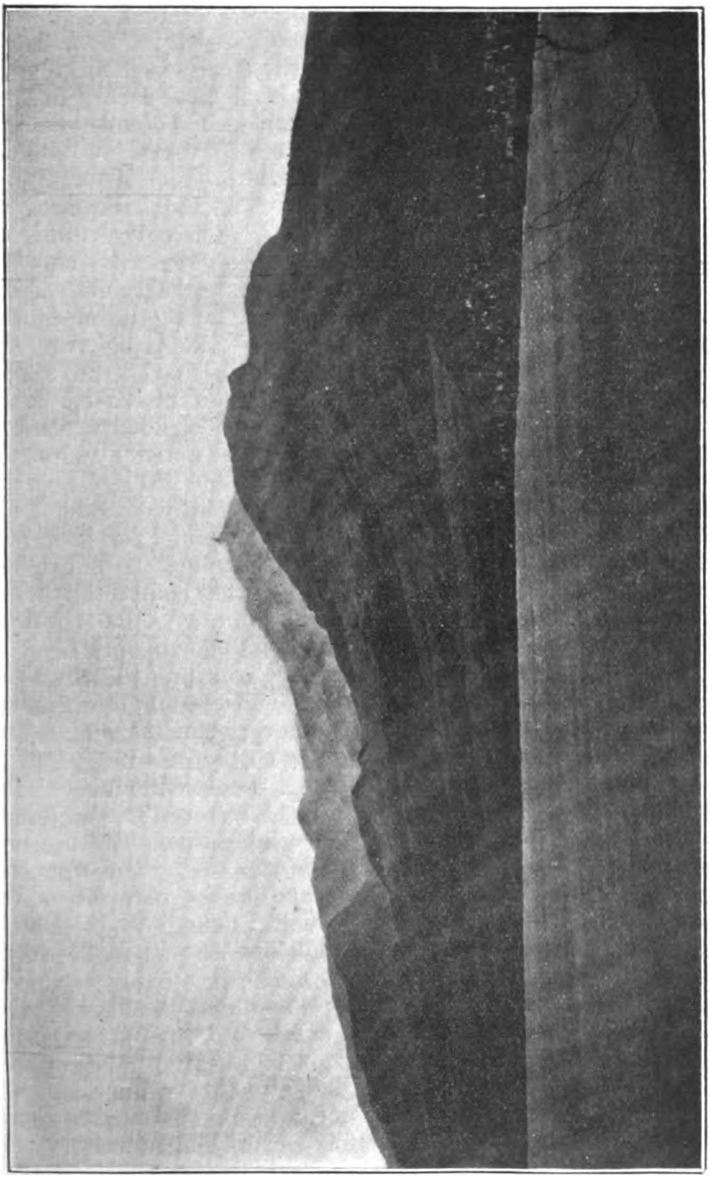
The Spine; July 6, 1902.

when the complete inner cone came into sight (figs. 2 and 3). Brown dust was rising in purling jets all over the surface, and heavier billows of white steam rose from the southeast side of the cone. Other steam-jets were observed in the Rivière Blanche.

On the summit of the cone was seen a most extraordinary monolith, shaped like the dorsal fin of a shark, with a steep and almost over-hanging escarpment on the east, while the western aspect of the spine was curved and smooth in profile. The field glass showed jagged surfaces on the steeper eastern side, and long smooth striated slopes on the western. Other horn-like projections from the cone could be discerned with difficulty on its slopes lower down. Similar horns were noted by Heilprin in August.* The great spine on the summit was not less than 200 feet high above the surface of the cone.

* Hovey, loc. cit. p. 272.

3



Mt. Pelée, looking N.E. July 6, 1902.

The Spine of 1903.

Comparing this spine with the greater one figured by Hovey* from photographs taken in March, 1903, it will be seen that it faces in the opposite direction, i. e. the steep scarp in Hovey's pictures faces west, in our photograph it faces east. In both cases there is a long curved constructional slope on one side and a broken cliff of destruction the other. Hovey has pointed out that the later spine was probably the product of conditions developed after August 30th, 1902. The two eruptions of July 9th and August 30th, 1902, were sufficiently violent to destroy the spine observed July 6th, by the present writer.

The steep cliff is clearly in both cases a destructional surface from which material has fallen away. The evolution of the later spine as observed by Major Hodder†, changing from the "lighthouse" shape to the "church steeple" (shark's fin) shape, seems to the writer to imply the blowing off or caving in of one side of a conical mass at first symmetrical about a central vent. This would account for the absence, noted by Hovey‡, of any "definite conduit through the spine itself," and the occurrence of heavy outbursts "from the southwest side of the cone near the base of the spine". The channel for such outbursts, at the base of the *steep* side of the spine, is the original central conduit of a domical mass which has completely caved in on one side, leaving the infacing spine as a half broken-down remnant. The process of breaking down may be gradual, and the upthrust from below may continue to act on the half destroyed residual spine. This will account for gradual changes of shape and fluctuations in elevation of the spine. The striated surface, if this explanation be correct, should be found on all sides of the monolith during the continuance of the "lighthouse" stage. This stage may be restored to the profile shown in the photographs by imagining the smooth curve repeated on the steep side of the spine so as to give it a sugar-loaf shape. Thus in July, 1902 (figs. 2 and 3), the east side of the sugar-loaf had been blown away or had flaked off; in March, 1903, the west side had been removed as shown in Hodder's diagrams.§

Granting that these horns are broken remnants of hard cone-shaped protuberances from the new pile of débris in the crater-gorge, there remains the question of the origin of these protuberances. They have dike ribs extending from them, and are composed of hard rock, fissured and glowing at times, but without associated lava *streams* of any sort. The cumulo-volcano

* This Journal, figs. 1 to 7, October, 1903.
† Hovey, loc. cit. pp. 273–275, and figs. 2 and 3.
‡ Loc. cit. p. 279. § Loc. cit.

theory of Lacroix supposes a "lava" to have risen from the deep regions to furnish material for the spine. This "lava," nearly congealed, "seems to have been pushed up bodily into its present position, and to be maintained there, somewhat like the stopper in a bottle, by friction against the sides of the neck and by the expansive forces underneath."* There can be no question of the evidence that shows the spine to have been pushed up in a semi-solid condition through fissures in the cone of débris. We may ask, however, this question,—may not the half-molten substances be a superficial product, resulting from the mechanical and thermal conditions that governed the building of the cone?

The writer's reasons for opposing the "lava" hypotheses are twofold: (1) None of the ejecta of Pleistocene times in the Caribbees are true lavas; (2) Even the more ancient geologic sections show few flows. If lavas are to flow from Pelée at this time, then these eruptions inaugurate a new era. This is improbable, for there have been eruptions in these islands averaging once in twenty-three years for over 300 years of human record, and the eruptions of the unrecorded previous centuries left no lava flows on the present or recent topography. The ejecta collected from the present and past historic eruptions are fragments of ancient andesites and basalts.

Theory of Origin of Spine.

The following is a suggested explanation of the origin of the spines, which does not require a flowing lava to rise into the throat of the volcano from deep-seated sources:—

The spines are small compared to the volume of material which has fallen back into the crater from many successive eruptions. This material fills not only the crater-gorge of the Rivière Blanche, but deep fissures of unknown size beneath the present cone. Such fissures have been enlarged below with every eruption, while at the same time bombs have been heaped upon the cone above.

The rocks ejected were observed to become more incandescent with successive eruptions and much of that which fell back on the cone consisted of large fragments half molten on the surface; there was much finer material mixed with these.

Accumulation of this pasty incandescent material with each new eruption produces increased pressure from above, and by conduction and radiation the heat is probably concentrated. The outer portions of the cone become crusted, a blast of hot gases and the steam traverses the open passages, and both

* Hovey, loc. cit., p. 278.

chemical and mechanical conditions favor the fusion and segregation within, of the more fusible minerals.

Rifting of the crust may take place by faulting, differential contraction, or by the action of escaping steam, and the molten matter slowly wells up under the pressure of the slumping agglomerate.

Exposed to the cooler air this viscid silicate mixture solidifies quickly and impedes the upward progress of the more liquid portions below.

The actual volume of the molten material would increase with many successive eruptions and diminish with cessation of eruption: it would *vary with the growth of the cone*, and this is what the spines have been observed to do. There can be no doubt that an enormous amount of red-hot material is confined in the cone and the fissures beneath; that it would remain incandescent for months even without additions is proved by analogy with the banks of hot gravel along the stream courses. These retain their heat for many weeks after an eruption; a rain-crust forms above, and the banked-in gravel causes frequent explosions when ground-water makes contact with it. If these banks so retain their heat at a distance of miles from the crater, much more will the temperatures within the cone be high and long maintained, for there the fragments are hottest and largest, are accumulated in greatest volume, are frequently added to, and are in contact with dust-laden steam and heated gases rising under pressure from unknown depths.

Even if no spines had appeared, one might ask on *a priori* grounds, What has become of all the pasty incandescent material that has fallen back into the crater and is now under pressure? It cannot be supposed to have hardened at once, and it must have been intimately mixed with pulverized rock of varying fusibility. It would seem dynamically probable, therefore, that such material would become agglutinated in fluid masses within the agglomerate of the crater fissure, and escape to form irregular protuberances along paths of least resistance.

ART. IV.—*The Action of the Halogen Acids upon Vanadic Acid;* by F. A. GOOCH and R. W. CURTIS.

[Contributions from the Kent Chemical Laboratory of Yale University—CXXIII.]

IN the study of the interactions between the halogen acids and vanadic acid in solution made chiefly with a view to the analytical applications, it has been shown that if conditions be suitably fixed, vanadic acid may be reduced definitely by hydrochloric acid and by hydrobromic acid to a condition of oxidation corresponding to that of the tetroxide, V_2O_4, and that hydriodic acid may carry the reduction to the stage of the tetroxide or to that of the trioxide, V_2O_3, according to conditions. It is the object of this paper to record some results of further study of the conditions of action between vanadic acid and the halogen acids.

The Reducing Action of Hydrochloric Acid.

It has been shown in an article from this laboratory* that the reaction of the process, according to which a suitable vanadate is treated with hydrochloric acid, the solution boiled, and the evolved chlorine determined as suggested by Bunsen,† noted by Mohr,‡ and utilized by Gibbs,§ is nearly complete in a single operation when the concentration of the hydrochloric acid is sufficient, and that an approximately correct determination of the vanadium may be made by the process when special care is taken to register all the chlorine set free. It appeared, however, that the reaction is reversible, and that in the ordinary process involving a single treatment of the vanadate with strong hydrochloric acid and boiling, the tendency to reverse is not fully overcome. When hydrochloric acid of suitable concentration and the vanadate come to contact, the evolution of chlorine is immediate, some chlorine escapes from the solution, some is retained, and the reaction proceeds to a balance as indicated in the expression

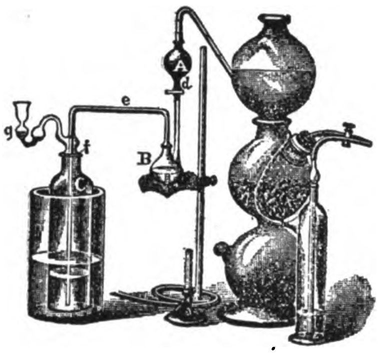
$$V_2O_5 + 2HCl \rightleftharpoons V_2O_4 + H_2O + Cl_2.$$

To complete the reduction of the higher oxide it is necessary to remove the free chlorine from the system while keeping up the requisite strength of the hydrochloric acid. In removing the chlorine by boiling, the concentration of the hydrochloric acid is diminished below the point at which action upon vanadic acid may take place with liberation of chlorine. This is why in pushing the action to completion by the boiling process, it is necessary to increase the concentration of the hydrochloric acid from time to time either by cooling and recharging with gaseous acid or by evaporating off the weak acid and replacing it by strong acid.

* Gooch and Stookey, this Journal, xiv, 369 (1902).
† Ann. Chem. (Liebig), lxxxvi, 265. ‡ Titrirmethode, 5te Aufl., 314.
§ Proc. Amer. Acad., xviii, 250.

In continuing the study of this reaction we have thought it desirable to try to effect the removal of the chlorine and to complete the reaction by bubbling a current of gaseous hydrochloric acid through the cooled residue of a single treatment by boiling. Under these conditions the hydrochloric acid must always be at the concentration of activity, though the removal of the chlorine must be slow since the current of gas should not be rapid enough to cause mechanical loss from the mixture.

The apparatus used in these experiments was similar to that employed in the former work to which reference has been made, and is shown in the accompanying figure. We have



used as the source of vanadic acid for the experiments to be described immediately, and throughout this paper, ammonium vanadate of known purity, standardized by the method of Holverscheit.*

In every experiment approximately 0·1 gm. of ammonium vanadate was first introduced into the reduction flask B. The air was expelled from the apparatus by carbon dioxide from the generator, the receiver C being charged with hydrochloric acid and the trap *g* with water. Concentrated hydrochloric acid (15^{cm^3}) was admitted through the stoppered funnel A, and the mixture was boiled. The deep red color produced when the acid was first added, gradually passed through green to blue. The flask was allowed to cool, carbon dioxide being admitted to fill the partial vacuum, and surrounded with ice. Hydrochloric acid gas was passed into the reduction flask, at the rate of one or two bubbles a second, through the solution for periods varying from ½ to 112½ hours, the solution turning brown at first and then changing to green or blue, according to the length of the period. For continuing the flow of gas for long periods small Kipp generators set up with sublimed ammonium chloride in large lumps, and concentrated sulphuric acid, were found very convenient, a single charge serving to keep up the flow continuously over night.

* Inaug. Dissert., Berlin, 1890, p. 48.

At the end of the operation the degree of reduction was determined by titrating the contents of the flask, after dilution, with potassium permanganate in presence of a manganous salt. The data of the experiments are detailed in the following table:

TABLE I.

Exp.	NH_4VO_3 taken. gm.	Time. hrs.	V_2O_4 per 0·1000 gm. of vanadate taken. Calculated.	Found.	Difference.
1	0·1022	½	0·0695	0·0619	0·0076
2	0·1121	17	"	0·0621	0·0074
3	0·1010	18½	"	0·0678	0·0017
4	0·0980	21	"	0·0658	0·0037
5	0·1044	30	"	0·0600	0·0095
6	0·1043	112½	"	0·0691	0·0004

The reduction of the vanadic acid to the condition of the tetroxide by the action of hydrochloric acid in the cold is obviously slow, as would be expected, but the results show that it may be made practically complete in this manner. No indication of reduction below the condition of the tetroxide by the agency of hydrochloric acid is apparent.

The Reducing Action of Hydrobromic Acid.

In Holverscheit's most excellent method for the estimation of vanadic acid the reduction, effected by the action of hydrochloric acid and small amounts of potassium bromide, is almost ideally complete to the condition represented by vanadium tetroxide. Under the conditions the concentration of the hydrobromic acid is low, and it was thought to be of interest to investigate the effect of more concentrated hydrobromic acid upon the course of reduction.

In the first six experiments recorded in the following table, weighed portions of ammonium vanadate were introduced into the reduction flask, the receiver and trap were charged with a solution of potassium iodide (3 gm.: 350^{cm^3}), the apparatus was filled with carbon dioxide, hydrobromic acid (15^{cm^3}) of sp. gr. 1·68 (made by distilling a mixture of potassium bromide and syrupy phosphoric acid) was introduced through the funnel and the mixture was boiled eight or ten minutes. On the addition of the acid the vanadate dissolved and the solution took on a light green color, which on heating changed to red-brown and finally to a clear deep green. After cooling, the degree to which the vanadic acid had been reduced was estimated in two ways—by determining by means of standard sodium thiosulphate the iodine set free in the receiver by the bromine evolved, and by oxidizing by standard iodine the reduced product in the flask. The latter process followed the lines recommended by Browning* and consisted essentially in neutralizing the acid in the reduction flask by potassium bicar-

* Zeitschr. anorg. Chem., xiii, 116.

bonate (in solution 1 : 5), adding an excess of twentieth normal iodine, allowing the mixture to stand twenty minutes (all without admission of air) then transferring to a larger flask, introducing a slight excess of twentieth normal arsenious acid, and titrating to standard blue with iodine.

In experiment (7) the aqueous hydrobromic acid was strengthened by cooling and passing in gaseous acid before boiling; and in experiment (8) the residue in the flask was submitted to several treatments of cooling, recharging with the vapor liberated by heating the strong aqueous hydrobromic acid, and boiling, in order to see the effect of varying the concentration, the bromine evolved by each boiling being determined, and finally the degree of reduction of the residue was estimated as usual. The results of these experiments are calculated upon the hypotheses that the vanadic acid is reduced (first) to the tetroxide, (second) to the trioxide, and (third) that the trioxide and tetroxide are left in mixture.

TABLE II.

Exp.	In 0·1000 NH_4VO_3 taken		Found; calc. as V_2O_4		Found: calc. as V_2O_3		Found; calc. as mixture from figs. for receiver	
	V_2O_4 gm.	V_2O_3 gm.	Flask gm.	Receiver gm.	Flask gm.	Receiver gm.	V_2O_4 gm.	V_2O_3 gm.
1	0·0699	0·0632	0·0913	0·0877	0·0418	0·0396	0·0521	0·0160
2	0·0699	0·0632	0·0879	0·0885	0·0397	0·0400	0·0513	0·0168
3	0·0699	0·0632	0·0849	0·0896	0·0384	0·0405	0·0502	0·0179
4	0·0699	0·0632	0·0858	0·0849	0·0388	0·0384	0·0549	0·0136
5	0·0699	0·0632	0·0854	0·0853	0·0386	0·0385	0·0545	0·0139
6	0·0699	0·0632	0·0841	0·0839	0·0380	0·0379	0·0559	0·0127
7	0·0699	0·0632	0·0945	0·0943	0·0427	0·0426	0·0455	0·0221
8*a*	0·0699	0·0632	.....	0·0860	.. ..	0·0389	0·0538	0·0146
8*b*			.....	0·1104	.....	0·0499	0·0295	0·0366
8*c*			.....	0·1291	.....	0·0584	0·0107	0·0535
8*d*			0·1258	0·1291	0·0569	0·0584	0·0107	0·0535

So it appears that increase in concentration of the hydrobromic acid tends to carry the reduction below the condition of the tetroxide; but the highest degree of reduction reached in these experiments corresponds to a mixture of one-sixth tetroxide and five-sixths trioxide.

Results somewhat similar were obtained with hydrobromic acid made (first) by acting with bromine upon naphthalene and purifying the gaseous acid by passing it through a column of red phosphorus, and (secondly) by passing the vapor of bromine with hydrogen over hot platinum somewhat after the synthetic method of Harding,* and sending the product through red phosphorus. In a single case in which the synthetic hydrobromic acid was used, the reduction, after three chargings of

* Ber. Dtsch. chem. Ges., xiv, 2085.

the liquid and boiling, apparently reached the stage of V_2O_3, but, inasmuch as the purity of the synthetic hydrobromic acid was not thoroughly established, we do not regard this particular result as wholly trustworthy.

The Reducing Action of Hydriodic Acid.

According to Rosenheim* vanadic acid is not completely reduced to the condition of the tetroxide by the hydriodic acid made nascent when sulphuric acid and potassium iodide interact, analytical results showing an apparent reduction of 80 per cent or less. A comparison of the calculated figures with the recorded amounts of the reagents and their standards raises the question as to whether the standards have not been interchanged in the computation,† and in this event Rosenheim's figures would approximate 100 per cent as nearly as could be expected under the described conditions of manipulation. Friedheim and Euler echo Rosenheim's statement.‡ Browning,§ on the other hand, has shown that good analytical results are obtained when solutions of the vanadate, one or two grams of potassium iodide and 10^{cm^3} of sulphuric acid of half-strength are boiled to a volume of about 35^{cm^3} and the residual solution is cooled, neutralized with an alkaline bicarbonate (after the addition of a tartrate to prevent precipitation) and treated for some time with an excess of iodine which is followed by an excess of arsenious acid, the last being titrated by iodine to the blue end-reaction in presence of starch.

In Browning's process the estimation of the reduced product in the residue is made the measure of action. In section A of the following table are given the results of experiments in which the treatment was conducted in an atmosphere of carbon dioxide and in which the determinations of the iodine collected in the receiver are set over against the determinations of the reduction in the residue by Browning's process, omitting the addition of a tartrate.

In section B are given results of experiments differing from those of section A in that in treating the residue the excess of iodine was added before neutralizing with potassium bicarbonate so that re-oxidation should not be effected in the sensitive alkaline solution by atmospheric oxygen rather than by the iodine which is measurable.

It will be noted that in every experiment the iodine found in the receiver indicates a trifling reduction beyond the condition of the tetroxide V_2O_4, averaging 0·0023 gm.; and the same in general is true in regard to those determinations of

* Inaug. Dissert., Berlin, 1888, p. 18.

† Compare the standard of solutions on p. 15 loc. cit. with the computed results of tables on pp. 15 and 18.

‡ Ber. Dtsch. chem. Ges., xxviii, 2070. § This Journal, ii, 185 (1896).

TABLE III.

Exp.	V_2O_4 in 0·1000 gm. NH_4VO_3 taken gm.	KI gm.	H_2SO_4 1 : 1 cm³.	Initial vol. cm³.	Final vol. cm³.	Reduction flask V_2O_4 Found gm.	Reduction flask V_2O_4 Error gm.	Receiver V_2O_4 Found gm.	Receiver V_2O_4 Error gm.
					A				
1	0·0699	1	10	..	35	0·0668	0·0031−	0·0700	0·0001+
2	0·0699	1	10	..	35	0·0692	0·0007−	0·0715	0·0016+
3	0·0699	1	10	..	35	0·0686	0·0013−	0·0718	0·0019+
4	0·0699	1	10	50	35	0·0696	0·0003−	0·0744	0·0045+
5	0·0699	1	10	45	35	0·0678	0·0021−	0·0704	0·0005+
6	0·0699	1	10	50	35	0·0690	0·0009−	0·0710	0·0011+
7	0·0699	1	10	60	35	0·0681	0·0018−	0·0738	0·0039+
8	0·0699	1	10	55	35	0·0689	0·0010−	0·0724	0·0025+
9	0·0699	·6	6	55	35	0·0679	0·0020−	0·0722	0·0023+
					B				
10	0·0699	1	10	55	35	0·0699	0·0000±	0·0713	0·0014+
11	0·0699	1	6	55	35	0·0713	0·0014+	0·0722	0·0023+
12	0·0699	1	10	80	35	.....	.....	0·0725	0·0026+
13	0·0699	1	10	75	35	0·0710	0·0011+	0·0718	0·0019+
14	0·0699	·6	4	55	35	0·0701	0·0002+	0·0709	0·0010+
15	0·0699	·6	10	55	35	0·0717	0·0018+	0·0745	0·0046+
16	0·0699	·6	6	55	35	0·0706	0·0007+	0·0734	0·0035+
17	0·0699	·6	6	55	35	0·0703	0·0004+	0·0727	0·0028+
18	0·0699	·6	4	55	35	0·0700	0·0001+	0·0731	0·0032+

the residue in the reduction flask, in which the iodine was added before the bicarbonate—the over-reduction in the residues of section B averaging 0·0007 gm. The determinations of reduction in the residue, in the series of section A, in which the neutralization took place before the addition of the iodine, uniformly show an incomplete reduction—amounting in the average to 0·0015 gm.—an effect which is without doubt due to the action of air upon the sensitive alkaline solution of the reduced vanadate.

It appears, thus, that under conditions of concentration in which in absence of the vanadic acid there is no tendency (barring the insignificant action of dissolved air) toward liberating iodine, a little more iodine is liberated by vanadic acid when acted upon by sulphuric acid and potassium iodide than would correspond to a reduction of vanadic acid to the condition of the tetroxide.

Concerning the action of concentrated hydrochloric acid and potassium iodide upon a vanadate, Friedheim and Euler* give analytical data which go to show that reduction of the vanadic acid goes nearly (97.2 per cent) to the condition of the trioxide V_2O_3, and venture the assertion that the incompleteness of the reaction is conditioned by the formation of an oxyiodide which is broken up by the hydrochloric acid

* Ber. Dtsch. chem. Ges., xxviii, 2071.

only at a concentration (volume) which can not be reached without danger to the retort in which the operation is conducted. Friedheim and Euler propose the addition of phosphoric acid to this end and give excellent analytical results to sustain the suggestion.

In the experiments of the following tables, made in the apparatus figured and described above, the reductions were

TABLE IV.

Exp.	V_2O_5 in 0·1000 NH_4VO_3 taken gm.	HCl conc. cm³.	KI gm.	Initial vol. cm³.	Final vol. cm³.	V_2O_5 found Flask	V_2O_5 found Receiver
			A				
1	0·0632	5	0·6	50	*	....	0·0323
--	....	--	--	--	2	0·0613	0·0627
2	0·0632	5	1	55	*	....	0·0327
--	....	--	--	--	2	0·0618	0·0637
3	0·0632	12·5	1	50	*	....	0·0378
--	....	--	--	--	2	0·0615	0·0644
4	0·0632	15	1	45	*	....	0·0372
--	....	--	--	--	2	0·0617	0·0642
5	0·0632	25	1	50	*	....	0·0518
--	....	--	--	--	2	0·0618	0·0657
			B				
1	0·0632	15	1	16	2	0·0618	0·0630
2	0·0632	--	--	--	--	0·0612	0·0627
3	0·0632	--	--	--	--	0·0617	0·0625
4	0·0632	--	--	--	--	0·0620	0·0630
5	0·0632	--	--	--	--	0·0616	0·0627
6	0·0632	--	--	--	--	0·0618	0·0628
7	0·0632	--	--	--	--	0·0617	0·0630
8	0·0632	--	--	--	--	0·0617	0·0629
9	0·0632	--	--	--	--	0·0616	0·0629
10	0·0632	--	--	--	--	0·0618	0·0630

made by the action of hydrochloric acid and potassium iodide. In series A varying concentrations were employed and the boiling was interrupted as soon as the vapor of iodine had disappeared from the flask and the contents of the receiver titrated without admitting air. The receiver was then replaced, the boiling continued until the volume remaining was about 2^{cm^3}, when the free iodine in the receiver and the reduced product in the flask were determined. In series B the boiling was carried at once to the final stage.

From these results it is apparent that the degree to which vanadic acid may be reduced by hydrochloric and hydriodic acids turns upon the concentrations. We have found no difficulty in carrying the reduction, in the apparatus described, to

* To the point when the vapor of iodine had disappeared from the flask—approximately 40^{cm^3}.

the condition of the trioxide without the addition of phosphoric acid. In fact, the presence of phosphoric acid may work disadvantageously when low volumes are reached by permitting a dangerous rise of temperature in the still liquid residue. This is shown in the following series of experiments in which 1 gm. of potassium iodide, 2$^{cm^3}$ of syrupy phosphoric acid (sp. gr. 1·70) and 0·1 gm. ammonium vanadate were treated, the initial volume being 60$^{cm^3}$.

TABLE V.

Exp.	In 0·1000 NH_4VO_3 taken		Final vol.	Reduction flask		Receiver	
	V_2O_4 gm.	V_2O_3 gm.	cm^3.	As V_2O_4	As V_2O_3	As V_2O_4	As V_2O_3
1	0·0699	0·0632	35	0·0693	----	0·0698	----
2	0·0699	0·0632	25	0·0705	----	0·0711	----
3	0·0699	0·0632	22	0·0711	----	0·0706	----
4	0·0699	0·0632	4	----	0·0606	----	0·0623
5	0·0699	0·0632	2	----	*	----	0·0617
6	0·0699	0·0632	2	----	0·0597	----	0·0612
7	0·0699	0·0632	1·7	----	0·0621	----	0·0613
8	0·0699	0·0632	1·6	----	*	----	0·0624
9	0·0699	0·0632	1·4	----	0·0604	----	0·0629

These figures indicate also that when the distillation is continued until the volume is about 35$^{cm^3}$, the condition of oxidation corresponds nearly to that of the tetroxide. When the residue is concentrated almost to dryness, the figures approach the value for the trioxide, but under the conditions they are of doubtful value; for, fumes of hydriodic acid are visible in the flask, more or less spattering occurs, and the temperature is such that a volatile compound of vanadium begins to distil.

In summary of the work described it may be pointed out that in the interaction of hydrochloric, hydrobromic, and hydriodic acids upon vanadic acid the degree to which the last is reduced depends, as would be expected in reversible reactions, upon the concentrations. It has been shown that hydrochloric acid is capable of carrying the reduction, even in the cold, to the condition of the tetroxide, and under none of the conditions tried does reduction go further: that hydrobromic acid, which in small concentrations gives a definite reduction to the condition of the tetroxide, may easily push the reduction well on toward the condition of the trioxide: that the reduction by hydriodic acid may be carried at will to either of the stages—that of the trioxide or that of the tetroxide.

* Flask broke.

Art. V.—*Development of some Paleozoic Bryozoa;* by Edgar Roscoe Cumings.

Introduction.

The development of Paleozoic Bryozoa has up to the present time received very little attention. The few scattering observations of Lindström,[18] Nicholson,[24] Shrubsole,[41] Vine,[47] and Ulrich,[44] leave the knowledge of the subject practically where it was at the outset. Nicholson devotes a chapter to a discussion of the development of the Monticuliporidæ, but does not go further than a criticism of the views of Lindström, in regard to the supposed ontogenetic relationship between *Monticulipora* and *Ceramopora*. Shrubsole's notions of the development of *Fenestella* are entirely erroneous, those of Vine are but little better, while Ulrich concurs with Nicholson in rejecting the views of Lindström.

The writer's researches during the past year, at the Yale University Museum, have resulted in the discovery of many unique facts bearing upon the development of certain Paleozoic and recent Bryozoa. Although this investigation is still in progress, it will not be out of place to present some of the results thus far obtained, reserving the details for monographic treatment later.

All the material used in this investigation of the development of *Fenestella*, *Polypora*, *Unitrypa*, *Hemitrypa*, *Paleschara*, etc., belongs to the collection of the Yale University Museum. The silicified Lower Helderberg and Hamilton Bryozoa were especially collected by Dr. C. E. Beecher with reference to the study of the stages of growth. Dr. Beecher has not only placed all this unique material at the writer's disposal, but has in every possible way lent his aid and encouragement to the work. For this aid, as well as for his profound interest in the difficult and too often neglected problems of paleobiology, the writer is deeply grateful.

General.

The development of recent Bryozoa has been studied by a large number of observers, among whom J. Barrois,[1-4] Calvet,[5a] Claparède,[6] Harmer,[9-12] Joliet,[15, 16] Metschnikoff,[21-23] Ostroumoff,[27] Pergens,[28] Prouho,[29-31] Repiachoff,[32-38] Seeliger,[40] Smitt,[43] and Vigelius[46] have contributed the most important results for the presedentary stages; and Barrois,[1] Nitsche,[25, 26] Braem,[5] Davenport,[7, 8] and Harmer,[11, 12a] for the early budding stages of the colony. While the latter are necessarily the only ones ever preserved as fossils, a brief review of the earlier development will help to make the discussion of the later much more intelligible.

The now generally accepted classification of the stages of growth and decline, proposed by Alpheus Hyatt,[13] has never been consistently applied to a colonial organism, such as are the Corals and Bryozoa, nor to one whose ontogeny presents the retrograde metamorphosis which characterizes the latter class. It must be borne in mind that a colony or stock composed of a number of individuals may be properly characterized as nepionic, while some of the individuals composing it are in reality mature, senile, or even dead. The nomenclature of Hyatt applies solely to an individual developing from an ovum, that is, in the case of the Bryozoa, to the *first individual of the colony.* It follows, therefore, that before the colony has reached a stage in which its genus or even its family is recognizable, the first zoœcium, which the author here proposes to designate as the *protœcium*,* has become mature (ephebic). The colony would thus be phylembryonic,† while the protœcium is ephebic. Probably no confusion would arise from this source, if the exact sense in which these terms are used in a specific case, whether as applying to the individual or to the colony, were distinctly stated. Since the development of a bud presents no parallel with the early stages in the development of an individual from an ovum, there can be no confusion of terms up to and including the typembryo. It will be convenient, therefore, to have for the growth stages of a colony a nomenclature which entirely avoids the confusion attending the use of the terms nepionic, neanic, etc. Hence, the writer would submit the following set of terms, composed of the appropriate age-indicating word, as above, combined with the Greek word *ἄστυ* (*ăsty*), a town or assemblage of dwellings: thus, *nepiasty*, *neanasty*, *ephebasty*, and *gerontasty*, meaning an infant, adolescent, mature, or senile colony; and *nepiastic*, *neanastic*, *ephebastic*, and *gerontastic*, the corresponding adjectives.

Description of Figures 1–15.

Figures 1–15.—Development of a Chilostomatous Bryozoan, *Schizoporella unicornis.* (After Barrois.)

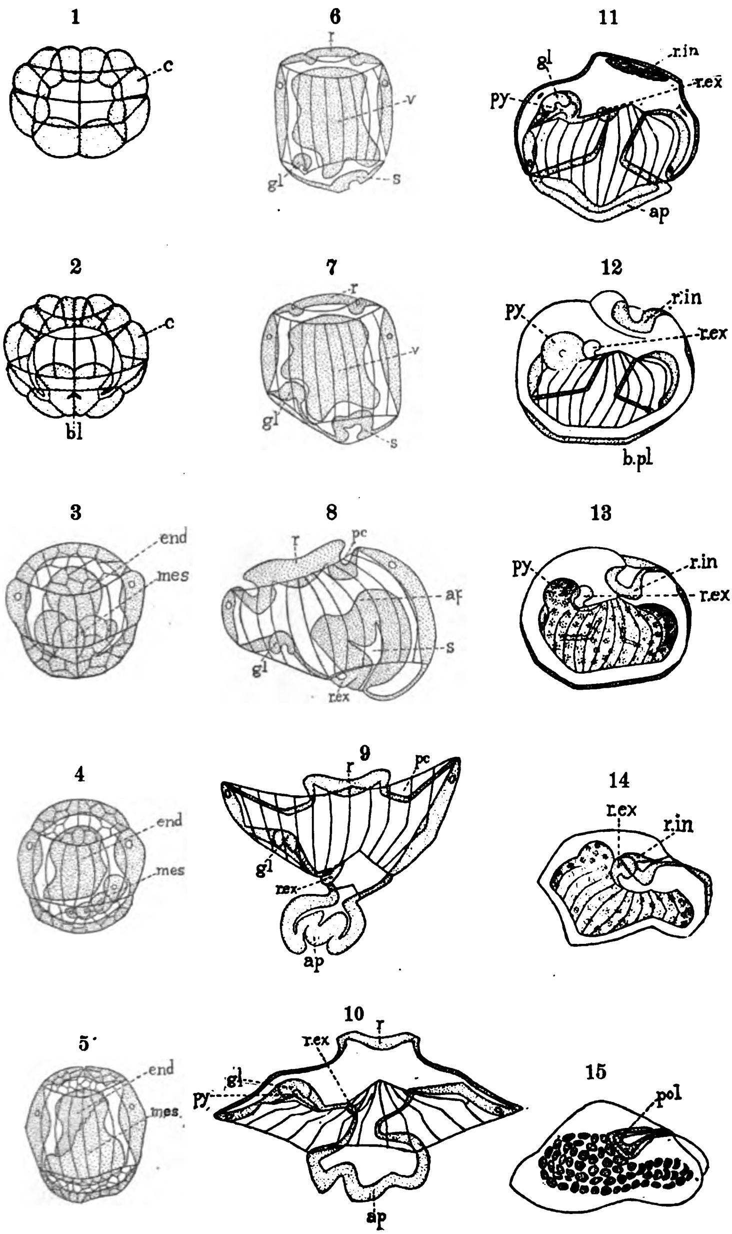
1. Mesembryo; 2. Metembryo; 3–5. Formation of the endoderm‡; 6, 7. Intermediate stages in the formation of the free-swimming larva; 8. Normal larva; 9. Evagination of the adhesive organ; 10. Reversal of the mantle; 11–14. Degeneration of the larval organs during the first sedentary stages; 15. First appearance of the polypide stage corresponding to fig. 26.

c, coronal cells; *bl*, blastopore; *end*, *mes*, endoderm; *r*, retractile disc; *s*, *ap*, adhesive organ (adhesive plate); *gl*, *py*, pyriform organ; *r.in*, rudiment of polypide; *pol*, polypide (double vesicle stage of Calvet[5a]).

All figures ×110.

* From πρῶτος, first, and οἰκίον, house or abode. † Jackson.[14]

‡ The investigations of Calvet[5a] have disproven the views of Barrois regarding the differentiation of the endoderm and mesoderm and the fate of the part marked *r.ex* in the figures. Nevertheless his figures present the general course of development with such clearness that it has seemed best to reproduce them and call attention to the points which lack full confirmation.



(For description see preceding page.)

I. *Classification of the Stages of Growth.*

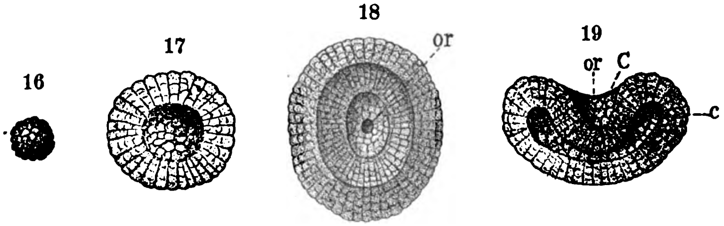
Embryonic Stages.

The *protembryo* includes the ovum and its segmented stages up to the formation of the blastula. Cleavage is total and almost equal (Korschelt and Heider[17]). The animal and vegetative poles can be distinguished by a slight difference in the size of their respective blastomeres.

The *mesembryo* (blastula) (fig. 1) is of lenticular shape, with a fair-sized cleavage cavity.

The *metembryo* (gastrula) (figs. 2, 3) is formed by the ingression of four endoderm cells. The coronal cells are defined at this stage (*c*, fig. 2) and later become very conspicuous. The four endoderm cells multiply so as to completely fill the blastocœle, thus forming a planula.

The *neoembryo* (figs. 4–8 and 17–25) includes the stages from the formation of the planula to the completed free-swimming larva (fig. 8). During these stages the endodermal cells multiply, according to Barrois[2] differentiating into endoderm and meso-



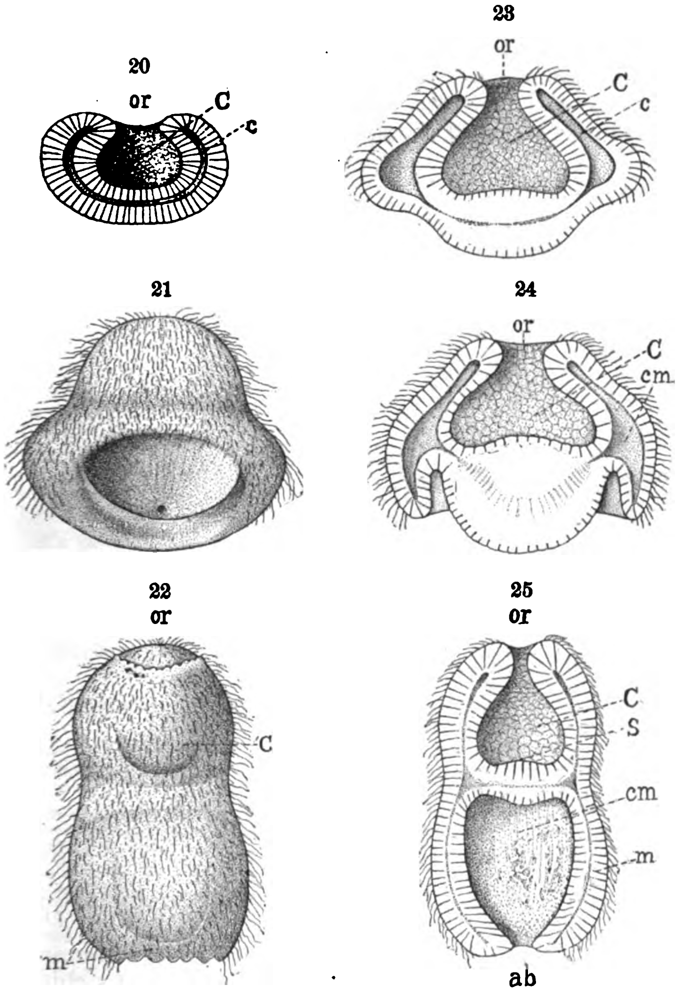
FIGURES 16–19.—Early embryonic stages of a Cyclostomatous Bryozoan, *Phalangella* (=*Tubulipora*). (After Barrois.)
16. Metembryo (pseudoblastula); 17, 18, 19. (Pseudogastrula) invagination of the adhesive organ; stages corresponding to figs. 6 and 7.
or, oral region; *C*, invagination cavity.
Figure 16 × 300; figures 17–19 × 160.

derm* (figs. 4, 5). The cells of the corona increase in size and become covered with cilia; a disclike thickening bearing stiff setæ, the retractile disc, develops in the aboral half. This is encircled by a depression,—the mantle cavity. An invagination develops in the posterior portion of the aboral half, to form the sucker, or adhesive organ (*ap*). An alimentary canal may develop at this stage in some types of larvæ (see figs. 31–35 and 22, 25).

The *typembryo* (figs. 9, 10) is formed by the evagination of the adhesive organ and reversal of the mantle (fig. 10). This gives rise to the first sedentary stage, which is passed through with great rapidity, and is immediately succeeded by a complicated metamorphosis involving the degeneration of most of the larval organs.

* This has not been observed by other workers.

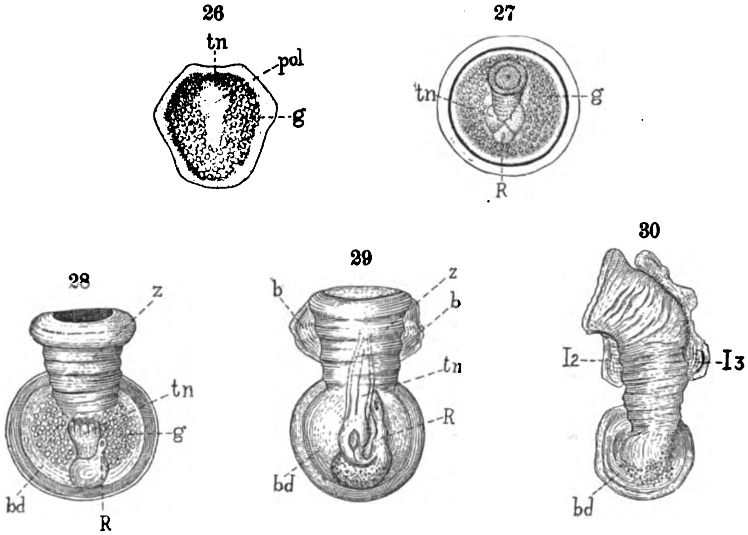
This metamorphosis, or *kathembryonic** stage, is not present in those organisms which pass directly from the larval to the



Figures 20–25.—Further stages in the formation of the free-swimming larva of *Phalangella* (= *Tubulipora*). (After Barrois.)
24 and 25. Optical sections of 21 and 22 respectively; 23. Beginning of formation of the mantle; 22 and 25. Completed larva.
or, oral region; *C*, invagination cavity of adhesive organ; *S*, adhesive organ (sucker); *cm*, mantle cavity; *m*, mantle.
Fig. 25 is modified from Barrois' original figure, in accordance with his later views.
All figures × 160.

* κατά, in the sense of opposition or contrast.

adult type of structure (Brachiopoda, Mollusca, etc.). The term is here proposed to cover the complicated degenerative metamorphosis of the Ectoproctous Bryozoa (figs. 11–15 and 26). During this stage the margin of the reversed mantle fuses with the margin of the extended and flattened adhesive plate, and the corona, pyriform organ, and larval intestine (where present) degenerate, forming a mass known as the brown body. The secretion of the ectocyst begins at this stage. The



Figures 26–30.—Formation of the polypide and protœcium in *Phalangella* (=*Tubulipora*). (After Barrois.)

26. An early sedentary stage, showing rudiment of polypide; 27. Beginning of tentacles and first zoœcium (protœcium); 28–30. Formation of first mature individual and primary buds, I_2 and I_3.

pol, polypide; *tn*, tentacles; *g*, globules formed by degeneration of larval organs; *R*, rectum; *z*, zoœcium; *b*, *b*, primary buds; *bd*, basal disc.

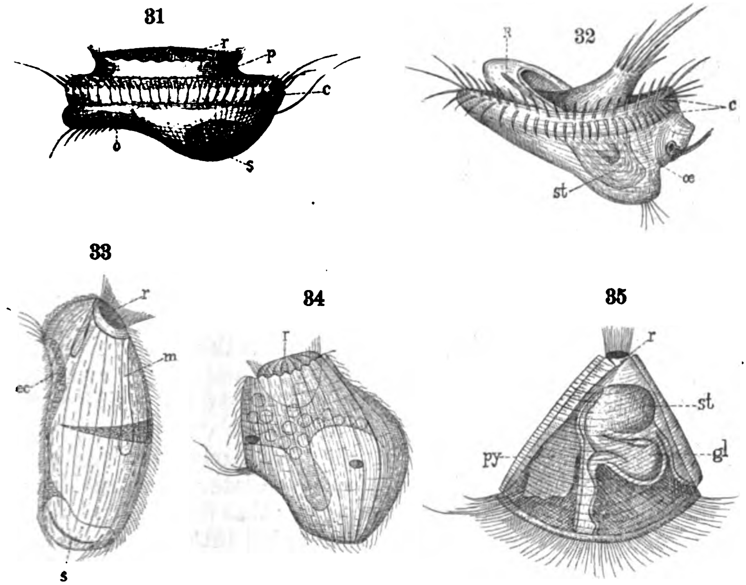
Figures 26–29 ×55; figure 30 ×40.

retractile disc is invaginated, and becomes the rudiment of the future polypide.*

The *phylembryo* (fig. 27) is characterized by the first appearance of the lophophore, the secretion in most types of a chitinous or calcareous investment, and the origin of the true alimentary canal. This is the earliest stage capable of fossilization. It closes with the origin of the primary buds. This first zoœcium of the colony is called the *protœcium*, or primary dwelling. The term *protœcium*, therefore, will not be exactly cognate

* According to Barrois[2] a paired organ (*r.ex*, figs. 8–14) shares in the formation of the polypide. On this subject, see Ostroumoff,[27] Vigelius,[46] Calvet,[5a] and Prouho[29] for a different view. See also the interpretation of the metamorphosis given by Harmer[12] and Sedgwick.[39]

with the terms *protegulum*, *protoconch*, *protaspis*, etc., as applied to the Brachiopoda, Cephalopoda, and Trilobita, respectively; for the latter terms signify the initial shell or covering of the individual and are not concerned with the adult, while the protœcium is the *initial zoœcium* of the colony and belongs to all growth stages of the initial polypide later than the kathembryo. From the standpoint of the colony the stage represented by the protœcium is *phylastic* (figs. 27–30).



FIGURES 31–35.—Types of free-swimming larvæ. (Figures 31, 32, 34, 35, after Barrois; figure 33, from Korschelt and Heider, after Barrois.)

31. Larva of *Alcyonidium*, a type which develops an alimentary canal; 32. Larva of *Loxosoma;* 33. Larva of *Serialaria*, vesicularian type; 34. Larva of *Bugula*, intestineless Chilostomatous type; 35. Larva of the *Cyphonautes* (*Membranipora*).

r, retractile disc; *p* and *m*, mantle cavity; *c*, coronal cells; *o* and *py*, pyriform organ; *s*, adhesive organ (sucker); *gl*, glandular organ; *st*, stomach; *R*, rectum; *œ*, œsophagus.

Figure 31 ×100; figure 32 ×116; figure 33 ×120; figure 34 ×133; figure 35 ×66.

The early development of the Cyclostomata presents some peculiarities that led Barrois[1] to mistake the metembryo (fig. 16) for a morula, and the early stages of the invagination of the adhesive organ (figs. 17–19) for a gastrula. This mistake has been repeated in a recent memoir on fossil Bryozoa. The development of the Cyclostomata, as pointed out later by Barrois,[4] Ostroumoff,[27] and others, quite closely parallels the development of the Chilostomata. The metamorphosis is similar.

Fig. 25 has been modified from Barrois' original figure in accordance with his later views.[4] The differences in the development of the Cyclostomata and Chilostomata consist mainly in the small size of the adhesive organ in the former, and the great size of the sucker invagination, together with the vestigial condition of the retractile disc and absence of the pyriform organ. The cylindrical shape of the Cyclostome larva is paralleled among the Chilostomata by *Serialaria* (fig. 33).

Classification of the Growth Stages of the Colony.

The *phylastic* stage has already been alluded to. This is the earliest stage capable of fossilization. It represents the period from the first appearance of a hard exoskeleton to the completion of the protœcium. In the Bryozoa, as pointed out by Barrois,[1] the exotheca at first differs considerably in appearance and texture from the more compact investment of later stages. The buds of the next generation (primary buds) originate at or slightly before the close of this stage. The protœcium frequently resembles the later formed zoœcia of ancestral types (Nitsche,[25] Pergens[28]).

The *nepiastic* stage is taken to represent the period from the formation of the primary buds, *i. e.*, those buds which are given off by the protœcium, to the establishment of the definite budding habit of the colony. The researches of Nitsche,[25] Pergens,[28] and others, have shown that the early budding habit frequently differs considerably from the later or normal habit of the colony, and more nearly resembles that of ancestral types. This stage may be conveniently subdivided into ana-, meta- and paranepiastic substages. The first, or ana-stage, will include the protœcium and completed primary buds. The meta-stage marks the termination of encrusting growth in forms that produce erect zoaria. The initial circle of buds in *Fenestella* belongs to this stage. The para-stage comprises the transition from the latter to the neanastic stage.

Figs. 36–43 show the primary buds of several types of recent Bryozoa. It will be noticed that in every case the first formed buds are *lateral*, and that a median bud may or may not be present. It is also noteworthy that only one of these eight types has more than three primary buds. The *Cyphonautes*, fig. 38, has six, an altogether exceptional number.*

* The order of budding is indicated by the small Arabic numerals, and the generation of a given bud by the Roman numerals. 1, indicates the median bud; 2, the left lateral; and 3, the right lateral bud. In the case of buds of succeeding generations the position number of each preceding generation is affixed to each bud, so that its entire ancestry is thereby expressed. For example, in fig. 39, bud No. IV_{3232} is of the fourth generation and was derived from the right lateral primary bud through the left lateral of the second generation, and the right lateral of the third generation. Where the same position

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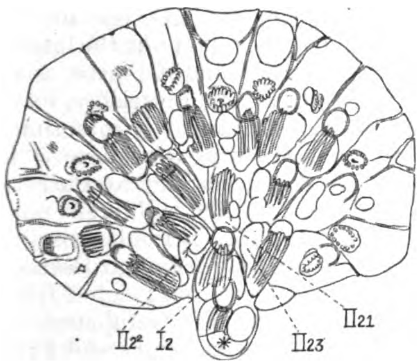

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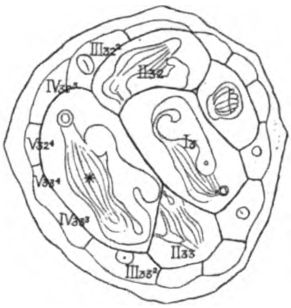

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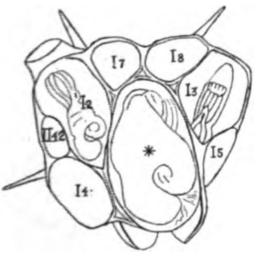

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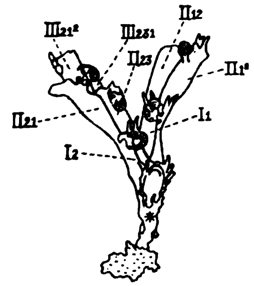

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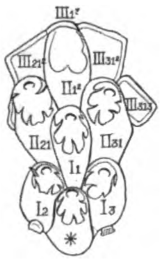

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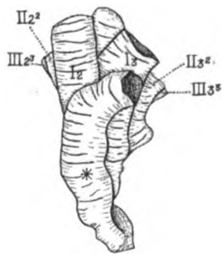


Figures 36–43.—Types of budding from the protœcium. (Figure 36, after Davenport; figures 37–43, after Barrois.) Protœcium marked by star. Order of budding indicated by Roman and Arabic numerals.

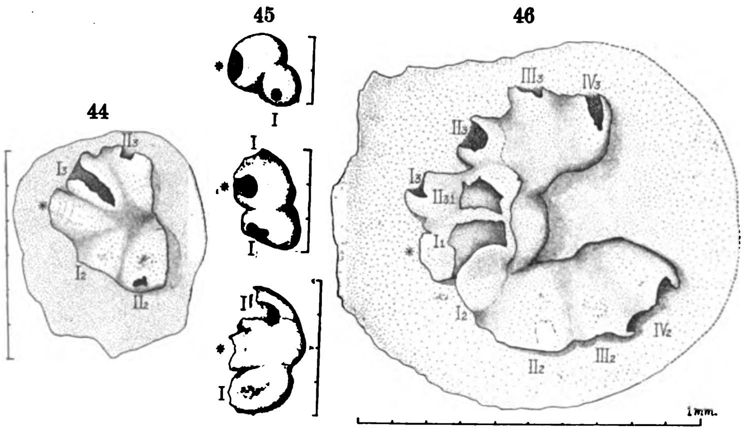
36. *Lepralia;* 37. *Alcyonidium;* 38. *Cyphonautes* (*Flustrella*); 39. *Schizoporella;* 40. *Microporella;* 41. *Bugula;* 42. *Membranipora;* 43. *Tubulipora.*

Figure 36 × 21; figure 37 × 35; figure 38 × 30; figure 39 × 30; figure 40 × 25; figure 41 × 10; figure 42 × 20; figure 43 × 20.

number is repeated consecutively an exponent is written to it; thus, in fig. 43, $III_3{}^3$ means III_{333}, *i. e.*, a bud of the third generation derived from the right lateral primary bud through the right lateral of the second generation. With slight modification this nomenclature would be equally applicable to the corals, or any other colonial type of organism.

In many cases, as in *Alcyonidium* (fig. 37), *Schizoporella* (fig. 39), *Lepralia* (fig. 36), and *Bugula* (fig. 41), one of the lateral primary buds is suppressed. Where but one of the lateral buds develops, it may be the right or left indifferently, as in *Alcyonidium* (Barrois[1]); or the right almost invariably, as in *Schizoporella*. In *Schizoporella* the left lateral is sometimes normally developed, but more often exists as a vestige or is totally lacking. Both lateral buds are, according to Barrois, never present together in *Alcyonidium*, but the indifferent position of the lateral bud indicates that the plan is fundamentally that of two lateral buds. In *Tubulipora*, according to Barrois' interpretation, I_3 (fig. 43) would be derived from I_2; but from the analogy of other Cyclostomata,* and from a careful study of Barrois' figures, the writer is disposed to consider I_2 and I_3 as in reality representing the two lateral buds. It will be seen later to what extent the development of two lateral buds from the protœcium prevails among all types of Ectoproctous Bryozoa. The ananepiastic stage is quite similar for all.

II. *Development of Fenestella.*



Figures 44–46.—Primary budding stages of *Fenestella coronis* from the Lower Helderberg (Shaly) limestones of Indian Ladder, New York.

45. Top figure, protœcium (*) and one lateral bud (I); middle figure, protœcium (*), one lateral bud and beginning of another (I, I); lower figure, protœcium (*) and two lateral buds (I, I); 44. Protœcium (*), two lateral buds (I_2, I_3) and two buds of the second generation (II_2 and II_3) arising from I_2 and I_3; 46. Protœcium (*) and buds of the 1st (I_1, I_2, I_3), 2d (II_2, II_3, II_{31}), 3d (III_2, III_3) and 4th generations (IV_2, IV_3).

All figures ×45.

* Harmer[11] has shown that two sister buds are thus derived from the protœcium in *Lichenopora*.

The *neanastic* stage begins with the assumption of the habit of budding that is to characterize the adult colony. In some cases (*Membranipora*, *Bugula*, *Alcyonidium*) this takes place very early, the meta- and paranepiastic stages being greatly abbreviated or entirely lacking. In other cases (*Fenestella*) the adult habit of growth is frequently not suggested until as many as fifty or sixty buds have been produced. The neanastic stage terminates with the development of an adult colony.

The *ephebastic* and *gerontastic* stages refer, as in other organisms, to fully adult and senile growths. The latter, especially, is marked by the extinction of the earlier polypides of the colony and frequently by profuse deposits of secondary sclerenchyma, as well as by other more or less extensive modifications affecting the basal portion of the zoarium.

Phylastic Stage.

The youngest observed specimens of *Fenestella* consist of minute globular bodies (fig. 45) of a diameter of about $0{\cdot}1^{mm}$, found upon the zoaria of *Orthopora*, *Callopora*, and other Bryozoa of the Lower Helderberg (Shaly) limestone of Indian Ladder, N. Y. These minute bodies represent protœcia, and have a definite aperture, but if the vestibule ever existed it has been broken away. That they are the protœcia of *Fenestella* is proved by their size relative to the zoœcia of adult colonies of that genus, and by the very complete series (figs. 44–46) of connecting stages, as well as by the presence of similar bodies on the bases of adult *Fenestella* colonies. The youngest individual figured (fig. 45, top) has already developed one lateral bud. The protœcium may frequently be recognized by its large size and significant position in the circle of zoœcia often to be seen on the base of well-preserved zoaria; it can be identified in transverse sections cutting the initial region of the colony, and especially in transverse serial sections of this region. Its exact relation to the primary buds has been repeatedly demonstrated in serial sections of exceptionally preserved calcified material. The evidence bearing on this point will be presented in a later paper.

Nepiastic Stages.

Ananepiastic Stage.—The initiation of this most interesting and significant stage in *Fenestella* conforms to the general plan that obtains throughout the Ectoprocta. It consists in the formation of two lateral buds (figs. 44–46, I_2, I_3) and later of a median bud (fig. 46, I_1). This order of budding has been verified in numerous specimens of *Fenestella* from widely separated horizons and localities. The lateral buds originate in

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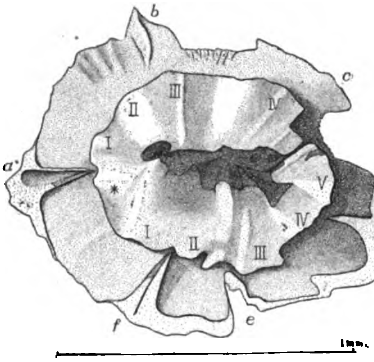

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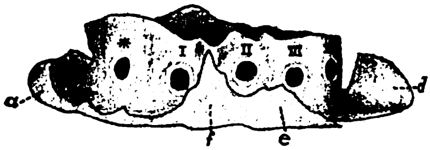

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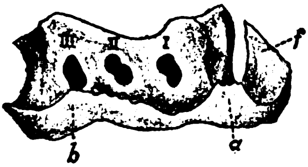

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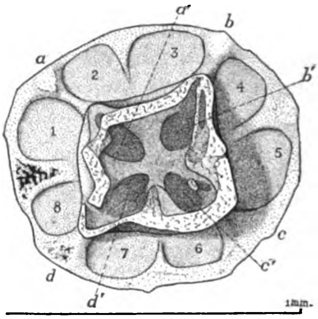

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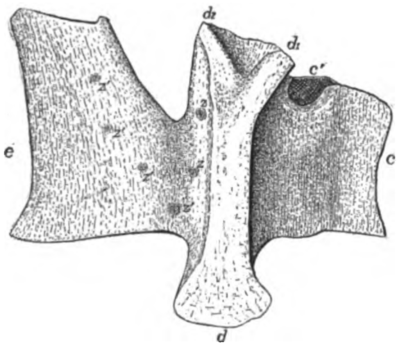

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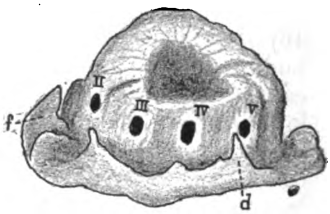

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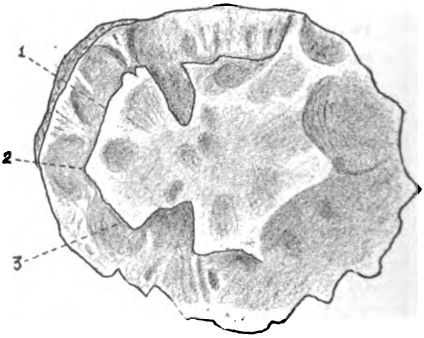

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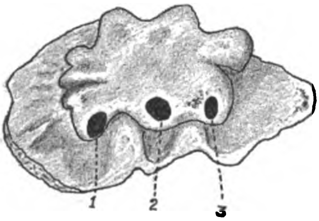

(For description see next page.)

such a position as to give a backward trend or deflection to subsequent budding, thereby giving rise to a hippocrepian (fig. 46) and later to a circular aggregation of buds (initial circle, metanepiastic stage, figs. 47–51) in which the protœcium occupies one end of a diameter, and the last formed bud of the circle, the other. The median primary bud arises from the top of the protœcium considerably later than the lateral buds, *i. e.*, at about the time of completion of the initial circle. It forms the first individual of the second tier of buds, which lie symmetrically above the first tier.

Metanepiastic Stage.—In *Fenestella* this stage consists of the completed initial circle of zoœcia. It has been seen that the ananepiastic stage trespasses on it to the extent that the median bud does not arise till near the completion of this initial circle. It constitutes an incrusting growth formed by budding in a horizontal plane, from which the adult colony arises by budding in vertical planes. Typically it consists of ten zoœcia including the protœcium, but there is considerable variation from this number even within the limits of a single species, so that initial circles of eight, twelve, or fourteen zoœcia are not uncommon, while in a peculiarly accelerated form found at Thedford, Ontario, only five of the typical number develop. In the latter, circles containing ten zoœcia arise only after several generations of zoœcia have been produced in vertical series. Such a zoarium is shown in fig. 55. The full discussion of this type of zoaria is deferred to a later time.

In certain cases the initial circle is arrested at a hippocrepian or semicircular stage, either because the full number of zoœcia fails to develop, or because the trend of the budding produces too great a divergence of the series of buds to the right and left of the protœcium. From a metanepiasty of this type, a flabellate zoarium will arise, unless subsequent growth is of such a nature as to bring the lateral margins of the zoarium together.

Description of Figures 47–54.

Figures 47–54.—Early stages in the development of *Fenestella* from the Hamilton limestone of Canandaigua Lake, N. Y. (47–50, 53–54), and the Lower Helderberg limestone of Indian Ladder, N. Y. (51, 52).

47–50. Top and side views of a young *Fenestella* slightly older than the individual shown in fig. 46. Initial circle of zoœcia complete and walls of neighboring zoœcia fused more completely than in 46. This specimen has ten (the typical number) zoœcia. The origin of the primary carinæ is shown at *a* to *f*. 51. Another specimen at about the same stage as 47, primary carinæ *a* to *d*. Each of the pits, *a'* to *d'*, corresponds to two zoœcia; a faint septum may be seen bisecting *d'*. The depressions in the basal plate (1 to 8) mark the position and limits of the exserted polypides. 52. Stage somewhat older than 51, showing first branching of primary carina (d_1, d_2) and three tiers of zoœcia (*z*, *z*, *z*, *z*, *z*, *z*). Note the great size and prominence of the carinæ. 53, 54. Another individual of the same age as 47.

All figures × 40.

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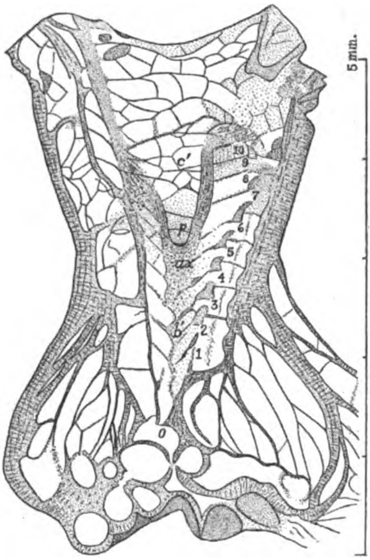

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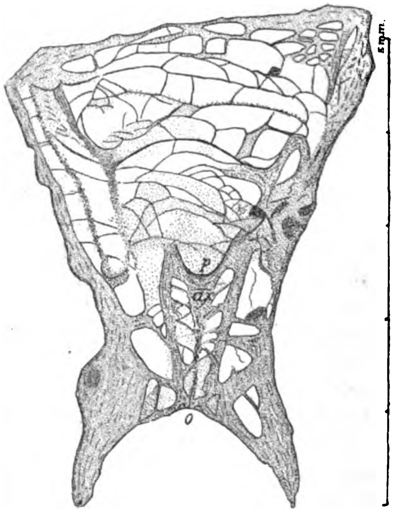

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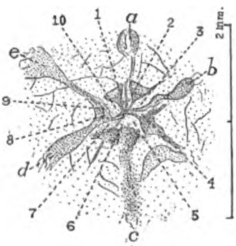

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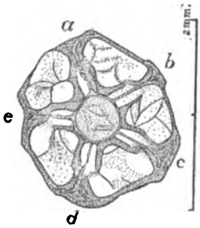

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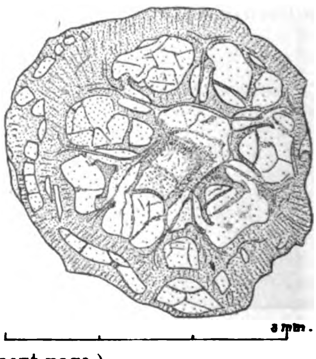

(For description see next page.)

In rare instances the initially flabellate zoarium curves in the reverse sense and by fusion of the meeting edges forms an infundibular colony which has literally been turned inside out. Such zoarial modifications have given rise to the maximum of confusion in the placing of species and genera of fenestrate Bryozoa, because in the adult colony lacking the base (as is almost invariably the case), the fundamental plan of budding is entirely obscured.

The carinæ originate during the metanepiastic stage.

Paranepiastic Stage.—Successive tiers of zoœcia are added above the initial circle until a cylindrical stem is formed which constitutes the stalklike base of the adult cone. The paranepiastic stage may be greatly abbreviated where the cone expands almost from the first circle of zoœcia, or it may be prolonged to five or six tiers of zoœcia (fig. 55). If such a cylindrical stalk is conceived of as slit longitudinally down the side diametrically opposite the protœcium and unrolled and flattened out, it will be seen that the protœcium lies at the base of a vertical series of zoœcia from which lateral branches are given off on either side. In other words, the budding follows Davenport's law that the median bud continues the ancestral row. It is not certain, however, that any importance is to be attached to this law.

Near the close of the paranepiastic stage the axis of the zoarium thickens preparatory to the expansion of the cone. This is well shown in figs. 55 and 56 (longitudinal sections) and figs. 58 and 62 (transverse sections) of specimens from the Hamilton of Thedford, Ontario. The thickened axis (*ax*) is composed of an outer wall continuous with the proper wall of the carinæ, and an inner dense deposit of punctate sclerenchyma. The section shown in fig. 60 cuts just at the top of this thickened axis.

DESCRIPTION OF FIGURES 55–60.

FIGURES 55–60.—Longitudinal and transverse sections of bases of *Fenestella* from the Hamilton formation of Thedford, Ontario.

55. Section of a *Fenestella* base cutting exactly in the plane of the axis and of the zoœcial apertures to the right (1 to 10). The initial zoœcium (protœcium) is at *o*; the thickening of the axis (*ax*) commences at *b'*; the apex of the cone of expansion of the colony is at *p*; the vesicular tissue (*c'*) above *p* is of secondary origin, forming during the mature and senile life of the colony. Fig. 56 shows the thickening of the axis, and oblique direction of the zoœcia, but does not cut through the zoœcial apertures. 57. Transverse section through the initial region of another individual (about in the plane of 1, fig. 55); *a–e*, primary carinæ; 1 to 10, primary row of zoœcia. 58. Transverse section through the thickened portion of the axis (about in the plane of *ax*, fig. 55) of another individual; *a–e*, primary carinæ (see also fig. 62). 59. Transverse section in the plane of *c'*, fig. 55, showing nine carinæ. 60. Transverse section in the plane of *p*, fig. 55, showing, in the lower portion of the figure, a carina just in process of branching.

All figures × 13.

Morphology of the Carinæ.—The primary carinæ first make their appearance in the metanepiastic stage, and are intimately related to the basal plate (figs. 47–54). In fact the carina seems to originate as an upgrowth or fold of the basal plate. It is structurally double or more properly triple (figs. 57–62), consisting of a thin median plate or wall continuous with the axial wall (*w*) and coinciding with planes of division between adjacent zoœcia; and on either side an outer layer of dense, punctate sclerenchyma. This median or proper wall, as it approaches the axis, becomes extremely thin, and is therefore apt to be destroyed, a fact that will account for the hiatus between *d* and *f* and the stalk of the zoarium in figs. 48 and 49. In early stages the carinæ are discrete, except near their junction with the basal plate, where they coalesce with the upturned rim of the latter (figs. 47, 51); but in ephebastic and gerontastic stages the earlier formed zoœcia become entirely submerged in a copious deposit of secondary sclerenchyma, which bridges adjacent carinæ, and gives a perfectly smooth cylindrical aspect to the stalk of the colony (cf. figs. 52, 58 and 60).

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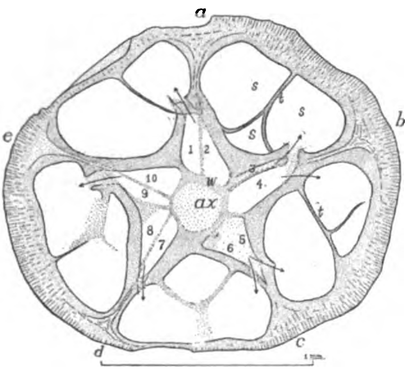

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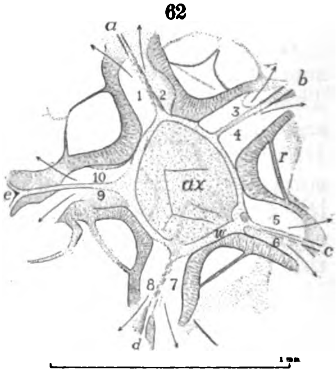

FIGURES 61, 62.—Transverse sections of base of *Fenestella* from the Hamilton formation of Thedford, Ontario. 61. Transverse section in the plane of *b′*, fig. 55, showing the presence of five primary carinæ and ten zoœcia. The heavy external wall joining *a*, *b*, *c*, *d*, *e*, is of secondary origin. In early stages the carinæ *a*, *b*, *c*, *d*, *e*, are discrete. The axis, *ax*, has a well-defined wall, *w*, continuous with the primary axes of the carinæ. 62. Same section as fig. 58—axial portion showing axial wall, *w*, and its continuation as the axes or midribs of the carinæ; *a–e*, carinæ; 1–10, zoœcia.
Figure 61 × 28; figure 62 × 31.

The height of the carinæ, breadth of the basal plate, and position and extent of the secondary deposits are sharply defined by the limits of action of the exserted polypides. The circular or semicircular depressions frequently seen in the

basal plate opposite the aperture of each zoœcium indicate very clearly the radius of action of each corresponding polypide (figs. 47, 51, 53, 54). It will be seen at once that the carinæ, without interfering noticeably with the movements of the exserted polypides, afford a very efficient means of protection against the snipping off, by some obnoxious visitor, of the tentacles of the polypides. That the danger of such rude treatment is by no means imaginary is abundantly proved by the fact that recent Bryozoa are frequently found with their tentacles lost or in various stages of regeneration. The carinæ also function as strengthening structures, especially in the basal portion of the zoarium, and may, by secondary deposits during later growth stages of the colony, be greatly increased in height and breadth. The completed nepiastic stage, with its strong carinæ, is strikingly suggestive, both in external appearance and in sections, of a segment of *Arthroclema*. (Cf. the axial region of fig. 55 with fig. 83, left.)

Neanastic Stage.

This stage begins with the assumption of the conical habit of growth. A plane passing through the apex of the cone (*p*, figs. 55 and 56), therefore, separates the nepiastic from the neanastic region of the zoarium. Fig. 52 shows a *Fenestella* just entering upon the neanastic stage. The nepiastic stage in this individual comprises three tiers of zoœcia or thirty zoœcia in all, including the protœcium. The first branching of one of the primary carinæ is shown at d_1, d_2. Fig. 60 shows the same phenomenon in transverse section. Fig. 59 shows a transverse section cutting the neanastic region of a slightly smaller zoarium, at a somewhat higher level. The vesicular tissue occupying the apex of the cone is of altogether secondary origin. It is deposited mainly during the gerontastic stages.

It will be noticed that the zoœcia of *Fenestella* lie always on the outside of the expanding cone, *i. e.*, they face away from the axis of the zoarium. It is also evident that this habit of growth is impressed upon the zoarium from the very outset. In any case where the initial circle of zoœcia (metanepiasty) is completed, the resulting zoarium will be a cone with the zoœcia on its outer surface. Where, for any reason, the initial circle is incomplete or abnormal, the resulting zoarium will, as has been pointed out above, be flabellate, or produce a cone by modifications arising during the neanastic stage. Such abnormal cones may, by reversal of the normal curvature, bring the zoœcia on the inside. *This fact does not, however, modify the*

fundamental type, which is determined by the position and orientation of the primary buds. It may, therefore, be positively asserted that, ontogenetically considered, the zoœcia of Fenestella always lie on the outer surface of the cone.

It is now necessary to consider the question of the original definition of *Fenestella*. Several authors have recently restricted this genus to forms having the zoœcia on the *inner* surface of the cone, notwithstanding the fact that Lonsdale,[19] in his original diagnosis of the genus, distinctly states that they lie always on the *outer* surface! It does not appear to the present writer that the fact that Lonsdale[20] afterward redefined the genus so as to make it practically coterminous with the whole family of Fenestellidæ, as at present accepted, has anything to do with the question. In any subsequent restriction of the genus by other authors, the original sense of the original publisher of the genus should have been ascertained and followed as closely as possible. The first species mentioned by Lonsdale under the newly erected genus is *Fenestella Milleri*, named after Mr. Miller, who had already proposed the genus in manuscript. *F. Milleri* clearly and unmistakably has the zoœcia on the outer surface of the cone. There cannot be the slightest doubt that *F. Milleri* represents Lonsdale's original conception of the genus. In the face of this fact the claims of *Gorgonia antiqua* and *Fenestella plebeia*, which Mr. Shrubsole[21] identifies with it, must be considered as worthless.

Ephebastic and Gerontastic Stages.

The detailed consideration of adult and senile stages of the zoarium of *Fenestella* raises certain points the discussion of which the writer prefers to postpone till a more complete survey of the specific representation of this and related genera can be undertaken. Enough has been determined, however, to make it certain that the founding of species upon slight variations occurring on small fragments of zoaria is an exceedingly questionable practice. The modifications of zoaria due to age may be profound. The writer has, for example, seen hundreds of specimens of most exceptionally well-preserved Lower Helderberg and Hamilton Bryozoa, in very many cases showing the entire zoarium. These specimens make it perfectly certain that many of the species that have been enumerated from these formations, and founded on fragments of zoaria, are spurious. They may often enough represent merely different growth stages of a single individual. *The only reliable criterion of a species is the entire zoarium.*

III. *Development of Unitrypa.*

The genus *Unitrypa* is characterized by the presence of transverse bars or scalæ, connecting adjacent carinæ at intervals corresponding approximately to the spacing of the zoœcia along the branches of the zoarium. Otherwise it conforms closely in habit and structure to *Fenestella.* The development of this genus reveals certain altogether remarkable features in connection with the origin of the scalæ, or carinal bars.

Nepiastic Stage.

The nepiastic colony of *Unitrypa* is an object of exquisite beauty, consisting of a delicate translucent cup wherein is lodged the pentamerously branching trunk or stalk of the zoarium, with its slender arching carinæ and diamond-shaped incipient scalæ (figs. 63–68). The presence of this perfectly formed cup is altogether unique, and its intimate relation to the carinal superstructure is beyond question.

The earliest stages (ana- and metanepiastic) of *Unitrypa* are indistinguishable from corresponding stages of *Fenestella.* Very early, however, the margin of the basal plate begins to curve upward into a shallow cup or saucer. At this stage the carinæ have not yet made their appearance, or are represented merely by slight ridges down the outer edges of the incipient branches (fig. 69). At a corresponding stage of *Fenestella* the carinæ are strongly marked (fig. 47). The margin of the basal plate continues to grow upward until a deep cup is produced surrounding the branching stalk of the zoarium (figs. 63–68). Near the termination of this stage each branch (a'–e') becomes united by a thin vertical plate (the carina) to the margin of the cup. This plate or carina sends out lateral processes about midway from the outer wall of the branch to the margin of the cup, at a point where the edge of the carina is abruptly deflected downward toward the wall of the cup (figs. 64, 65 and 69). The plane of these lateral processes is about parallel to a plane tangent to the wall of the cup where the carina joins it. In later stages these diamond-shaped processes are seen to coalesce midway between adjacent carinæ, so as to form transverse bars or scalæ. The processes are therefore the rudiments of scalæ (fig. 70). The margin of the cup is frequently scalloped in a manner conforming to the curvature of the basal margins of these incipient scalæ.

The primary branches originate at about the third or fourth tier of zoœcia (fig. 69). The basal plate is indented opposite the aperture of each zoœcium of the initial circle. The neanastic and later stages of *Unitrypa* are quite similar to corresponding stages of *Fenestella.* The zoœcia are carried up the

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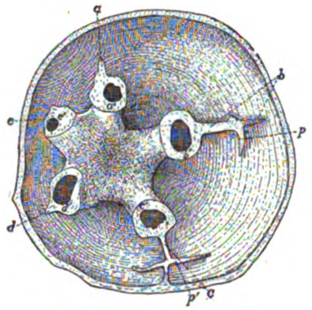

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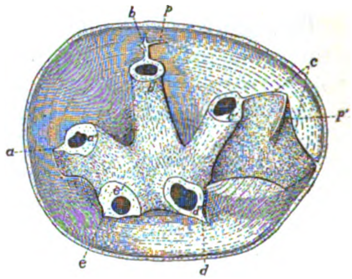

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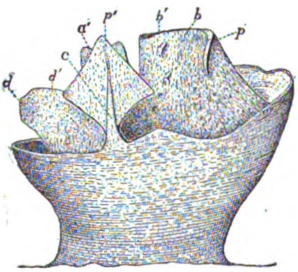

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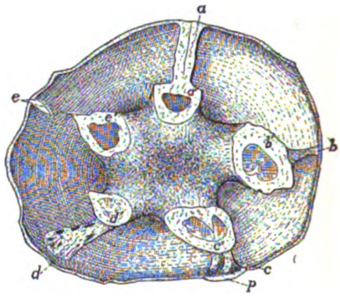

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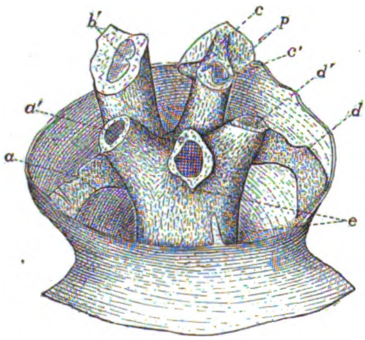

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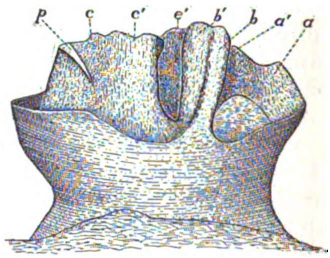

Figures 63–68.—Early stages of *Unitrypa* from the Lower Helderberg (Shaly) limestone of Indian Ladder, N. Y.

63–65. Top, oblique, and profile views of an individual showing five primary branches (*a'* to *e'*), five carinæ (*a* to *e*), and transverse plates (*p*, *p'*). Fig. 64 shows that the carina does not reach the bottom of the cup. In fig. 65 the plate *p'* is seen to be of diamond shape, extending laterally from the carina, while the parallelism between the slope of the plates and the wall of the cup is well shown at *p*. 66–68. Another individual showing similar features. The hiatus between the carinæ and the bottom of the cup is beautifully shown at *a* and *d*, fig. 67, and one of the transverse plates at *p'*, fig. 67, and *p*, fig. 68.

All figures ×26.

branches in double rows in precisely the same way as in the latter genus. The presence of scalæ is the only distinguishing character. In *Unitrypa* as in *Fenestella* the zoœcia are always on the exterior surface of the cone.

Homology of Parts in Unitrypa and Fenestella.—The carinæ are undoubtedly homologous in the two genera. They do not, however, reach the bottom of the cup in *Unitrypa*, or

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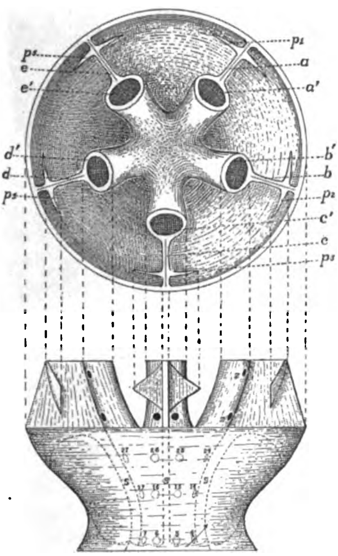

FIGURE 69.—Plan and elevation (semi-diagrammatic) of young *Unitrypa* of the stage shown in figs. 63–68. *a–e*, primary carinæ: *a'–e'*, primary branches; p_1–p_5, transverse plates (scalæ). The zoœcia are numbered to correspond to fig. 61. Three rows are present below the margin of the cup and two above. The probable orientation of the exserted polypide is shown by the arrow at 4. The basal plate is indented opposite each zoœcium as in the young of *Fenestella*. × 26.

at least if they did their inner portion was too delicate to be preserved (figs. 64, 67, 68). The cup is in appearance unlike anything to be found at a corresponding stage in *Fenestella*. Nevertheless there are strong reasons for considering it as homologous, in the main, with the basal plate of the latter. The rim of the cup may, however, represent one or more of the earlier scalæ fused with the margin of the basal plate. The scalloping of the rim suggests this latter interpretation. The cup might very well overspread the entire outer surface of the zoarium were it not for the necessity of adequate circulation of water over the zoœcia. This condition is approximated in some types (*Isotrypa*, *Semicoscinium*).

It is not unlikely that the form and position of the carinæ and carinal superstructures (scalæ, etc.) is very largely determined by the same necessity which, in the writer's opinion, has, in the case of the Brachiopoda and Pelecypoda, given rise to shell plication, namely, that of admitting water and excluding enemies. The protection afforded by such structures as the scalæ of *Unitrypa* and the still more elaborate superstructure of *Hemitrypa** is very complete. Of course any such

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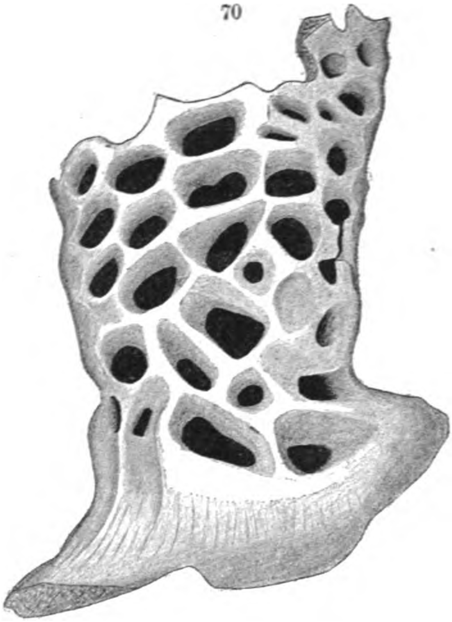


Figure 70.—Base of a neanastic *Unitrypa*, showing obliquity of transverse plates (scalæ), and thickened and modified representative of initial cup. × 20.

advantage is gained at the corresponding disadvantage of less perfect circulation of water over the zoœcia than is the case where they are unprotected.

IV. *Development of Polypora.*

Nepiastic Stages.

Ananepiastic Stage.—The earliest observed stage of *Polypora* consists of the protœcium and five encircling zoœcia (figs. 71–77). Even at this early stage the primary branches, seven

*** Thin sections indicate that the early nepiastic stages of *Hemitrypa* are identical with those of *Fenestella*.**

in number, are defined (figs. 72, 73, *a–g*). In *Polypora* the distal margin of the zoœcia is elevated, so that by careful inspection of the initial region of a young colony, the initial (central) zoœcium can be readily identified. In transverse sections, also, of the base of adult colonies the primary zoœcia can be easily determined (fig. 77). In the section shown herewith, the protœcium, because of its lower position, and more intimate contact with the substratum, had been broken open from beneath through its thin basal plate, and infilled with the iron-stained material of the matrix, thus making it a very conspicuous object in the transparent section. The primary zoœcia are arranged very symmetrically about the protœcium,—one in front, two to the right, and two to the left. There can be no doubt that the individual in front and the anterior pair of lateral individuals represent the median and lateral buds. Whether the posterior pair of lateral individuals represents another set of lateral primary buds or was derived from the anterior lateral buds cannot at present be definitely settled. Certain silicified specimens of *Polypora*, showing the initial region at the base of the zoarium, make it practically certain that the zoœcia in question were derived from the anterior lateral buds. In *Retepora phœnicea*, which has exactly the same arrangement of zoœcia about the protœcium as *Polypora*, these posterior buds are undoubtedly derived from the anterior laterals.* The buds marked II in fig. 77 are manifestly not derived from the protœcium.

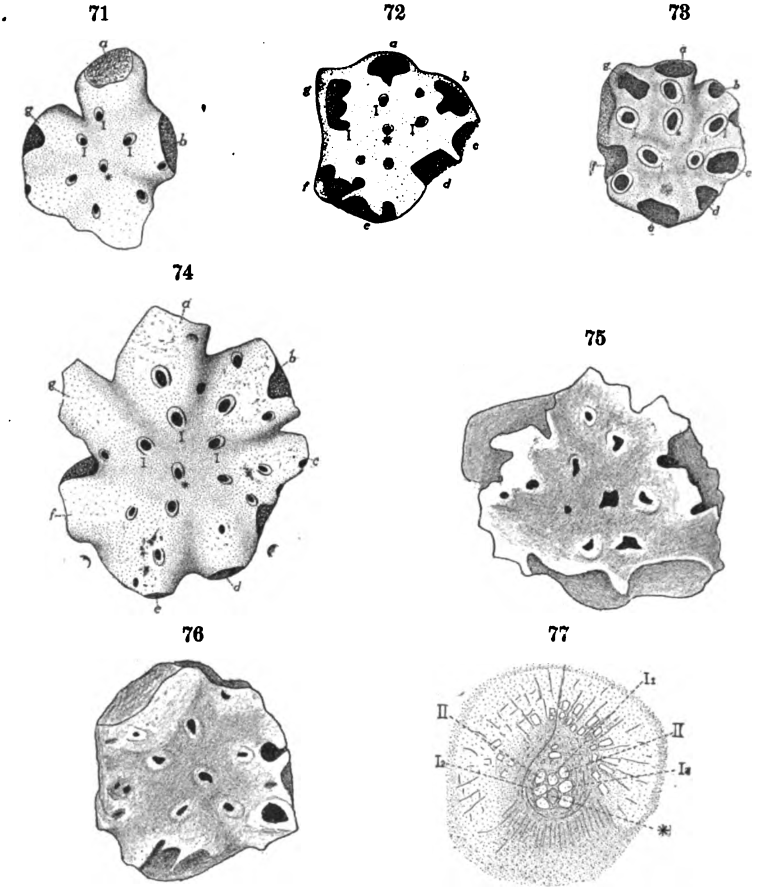
If the posterior pair of laterally placed buds is not primary, *i. e.*, derived from the protœcium, the stage represented in fig. 77 is to be regarded as metanepiastic, since the branching and ascent of the colony from the surface of support commence with the formation of the next circle of buds. Fig. 73 shows an individual just entering the neanastic stage. The meta- and para-stages are therefore greatly abbreviated in *Polypora*.

Comparison with Fenestella.

It requires no very minute inspection of the nepiastic stages of *Fenestella* and *Polypora* (cf. figs. 77 and 57; 76 and 46; 73 and 47; 74 and 52) to reveal a profound difference in the development of the two genera. The median bud of *Polypora* arises in front of the protœcium, instead of on top as in *Fenestella*. The protœcium of *Polypora* is surrounded by subsequent zoœcia and therefore comes to occupy a central position. In *Fenestella* the protœcium remains one of a more or less complete circle of zoœcia, and is in no sense central in position. The zoœcial apertures face upward and toward the axis of the zoarium in

* The budding order has been determined by the writer, in *Retepora phœnicea*, from St. Vincent's Gulf, S. Australia. Specimens showing the protœcium alone, and the protœcium and three primary buds, are now in the Yale University Museum, and will be described in a later paper.

Polypora, but outward and away from the axis in *Fenestella*. *In normally developed Fenestella cones, therefore, the zoœcia*



FIGURES 71-77.—Nepiastic stages of *Polypora*.* 71-76. Young individuals showing the protœcium (*) and primary buds (I, I, I) and the beginning of the primary branches (*a* to *g*). Fig. 74 (paranepiastic stage) shows the latter feature very perfectly. 77. Section through the base of an individual from Thedford, Ontario, showing protœcium (*) surrounded by seven zoœcia, five of which are in contact with it. I_1, I_2, and I_3 must have arisen from the protœcium.
Figures 71-74 ×26; figures 75-76 ×30; figure 77 ×13.

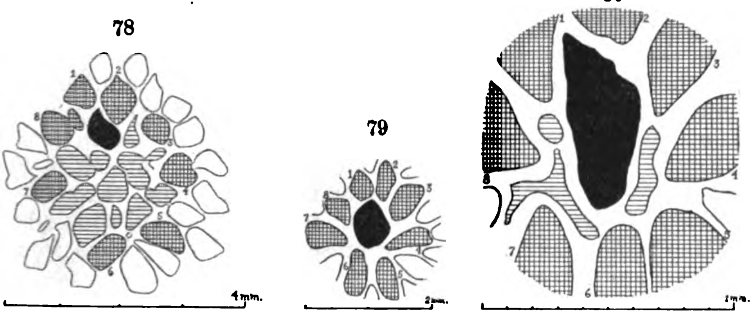
are always on the outer surface of the cone, while in normally developed Polypora cones the zoœcia are always on the inner surface of the cone. The type is determined by the position and orientation of the primary buds.

* Compare with these figures, Ulrich's figures of *Sphragiopora*. Geol. Sur. Illinois, viii, pl. lxv, figs. 6, 6a.

In *Polypora* as in *Fenestella* a partial or asymmetrical development of the metanepiasty may give rise to flabellate forms, and by reversal of curvature an occasional cone may arise in either genus, with the zoœcia on the surface opposite the usual one, *i. e.*, the zoarium may turn inside out. Such variations in no way modify the fundamental type.

Notwithstanding, therefore, the insistence with which authors have proclaimed the intimate connection between *Polypora* and *Fenestella*, such supposed close relationship is only another case of morphological equivalence. Waagen and Pichl's[48] erection of subfamilies for the reception of these respective types is more than justified by unmistakable evi-

78 79 80



FIGURES 78–80.—Initial zoœcia of *Paleschara* from the Lower Helderberg (Shaly) limestone of Indian Ladder, N. Y. Black = protœcium; cross-hatched (1 to 8) = primary buds; cross-lined = interstitial buds of a later generation. 1, 2, and 3 are in immediate contact with the protœcium.
79–80. Lower surface of the colony; 78. Upper surface. The primary zoœcia diverge rapidly in passing to the upper surface.
Figures 78, 79 × 8; figure 80 × 32.*

dence, of the existence of which those authors were, however, entirely ignorant. *Fenestella* and *Polypora*, as now constituted, comprise a heterogeneous assortment of forms, partly belonging to outside genera and partly entitled to remain where they are. When the correct generic relationships of these forms are determined, the proper arrangement of genera will be to place all forms having the nepiastic stages as in *Fenestella* in the family *Fenestellidæ*, and all forms having the nepiastic stages as in *Polypora* in the family *Polyporidæ*. *Thamniscus* will not belong to either of these families. The position of the other genera now referred to the family Fenestellidæ as at present constituted, can be determined by an investigation of their development. The writer does not venture an opinion beyond the limits of the types already so

* The numbers 1, 2, 3, etc., in these figures are not intended to indicate the order of budding.

studied. Certain persistently flabellate forms should, however, be placed in appropriate genera, as suggested by Simpson.[41]

The number of rows of zoœcia, which has been considered the chief differential character between *Polypora* and *Fenestella*, is of altogether subordinate value. Carinæ do not occur in *Polypora*. It is believed that there are physiological as well as developmental reasons for this.

V. *Development of Paleschara.*

Two specimens of *Paleschara* from the silicified Lower Helderberg material show the initial region of the zoarium (figs. 78–80). The protœcium is slightly larger than the other zoœcia and is closely surrounded by eight buds. Whether these all originated from the protœcium cannot be determined; from the analogy of other Bryozoa the belief would be justified that they did not. It is significant that their number and arrangement are the same as in the recent genus *Microporella*. The zoœcia numbered 1, 2, and 3 in the figures are in more intimate contact with the protœcium than the others (4–8) and may represent the median and lateral buds. From the analogy of *Microporella*, however, the median bud should be lacking; and 3 and 8 should represent the lateral buds from which 1 and 2 were produced.

VI. *Conclusions.*

In general all Bryozoa, both recent and fossil, thus far studied, conform to a fundamental plan of primary budding. This consists in the development from the protœcium of one or two lateral buds and frequently of a median bud which arises somewhat later.* Any apparent departure from this plan is found on closer inspection to conform to it. *Fenestella*, *Unitrypa*, *Polypora*, and probably *Paleschara* conform strictly to this plan of budding.

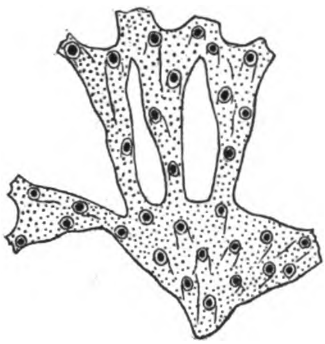
In *Fenestella* the primary buds arise in such a position and are so orientated as to cause the apertures of all subsequent zoœcia to face *away from* the axis of the zoarium. In *Polypora* the primary buds arise in such a position, and are so orientated as to cause the apertures of all subsequent zoœcia to face *toward* the axis of the zoarium. This difference is taxonomically of *family* value. In certain cases the full number of buds may be lacking in the metanepiastic stage, or, when present, they may have an unusual arrangement, and give rise, for either reason, to asymmetrically developed or flabellate colonies. Such

* This fact will afford a solution to the systematic position of the Trepostomata, since the budding from the *protothека* (πρῶτος + θήκη) of corals follows an entirely different law.

colonies arise in both the Fenestellidæ and Polyporidæ, and may be produced with such persistence as to give rise to flabellate genera. In other cases they occur sporadically, and undoubtedly in its phylogenesis this peculiarity first occurred only in occasional individuals.

The carinæ of *Fenestella* originate as septal upgrowths of the basal plate, coinciding with planes of division between adjacent zoœcia. They are manifestly protective and strengthening structures.

82



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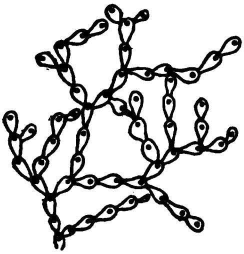

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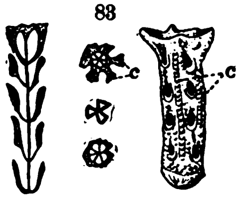

FIGURE 81.—*Stomatopora* from the Trenton of Minnesota, showing the propagation of the colony by simple linear budding, or by formation of two lateral buds. × 6.

FIGURE 82.—*Proboscina* from the Trenton of Minnesota, showing incipient coalescence of branches. × 12.

FIGURE 83.—*Arthroclema* from the Trenton of Minnesota, with transverse and axial sections of another species. Compare with axial portion of fig. 55. Sections × 13; other figures × 9.

Unitrypa and *Hemitrypa* conform in their ana- and metanepiastic stages to *Fenestella*, but differ from the latter in the production, during the paranepiastic stage, of a peculiar cup, surrounding and embracing the basal stalk of the zoarium. This cup represents the upgrowth of the margin of the basal plate, and the fusion therewith of one or more series of primary scalæ, through acceleration of growth of the latter structures. In their ontogenesis the scalæ are intimately related to the

carinæ, and represent a further elaboration of the latter for protective purposes.

It is still too early to attempt a phylogenetic classification of the Ectoprocta. The present studies will, it is believed, indicate the direction in which such a classification must be sought. The budding of all colonial organisms, after the primary stages, is apt to be very irregular, since the growing colony as it increases in size is more and more compelled to accommodate itself to the limitations of space and food supply. Only the nepiastic stages, therefore, have any phylogenetic value or any classificatory value higher than generic. The uniformity of the nepiastic stage in Bryozoa (Ectoprocta) suggests a common ancestor, which propagated by means of lateral buds, forming bifurcating series.* *Stomatopora* presents this type of budding, rarely producing a median bud in addition to the two lateral ones. Where there is a linear series of buds, the writer is disposed to consider the individuals of such a series as representing unpaired lateral buds (fig. 81). Some specimens of *Stomatopora* very forcibly suggest this interpretation.

Through *Proboscina* (fig. 82) and related forms, the genetic line from linear and anastomosing zoaria like *Stomatopora* to true incrusting forms is very complete; and the development of *Fenestella* seems to show how cylindrical and infundibular zoaria may be derived from incrusting zoaria. The ancestors of the Ectoprocta (Cyclostomata, Cryptostomata, Chilostomata) may be sought, therefore, in the direction of *Stomatopora*-like types.

Further than supplying a method, the present studies have done little to clear up the mystery of the Trepostomata. In the writer's opinion, they indicate a rather more remote relationship between this and other orders of Bryozoa than certain authors have held. The Trepostomata are a very ancient type, but they probably do not stand in a linear relation to any other order of Bryozoa.†

The author's studies strengthen the view advanced by Ulrich[46] that the Cryptostomata are the Paleozoic representatives of the Chilostomata. *Polypora* and *Retepora* are precisely alike in their early budding stages.

November, 1903.

* Davenport[7] holds a somewhat different view.

† *Phylloporina* is a composite genus in no way ancestral to *Fenestella*. *P. corticosa* belongs to the Trepostomata.

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ART. VI.—*Effects on Rare Earth Oxides produced by Radium-Barium Compounds and on the Production of Permanently Luminous Preparations by Mixing the Latter with Powdered Minerals;* by CHARLES BASKERVILLE and GEORGE F. KUNZ.

THE following rare earth oxides in powdered condition were mixed with radium-barium chloride of 240 activity. The mixture was shaken in test tubes and carefully observed in the dark to note any luminosity. None was observed with any one of the oxides. The following oxides were used: thorium, zirconium, titanium dioxides; zinc, cerium, lanthanum, yttrium, ytterbium, erbium, a mixture of the last three, praeseodidymium, neodidymium, lanthanum, gadolinium, samarium and uranium oxides.* They were not examined with a microscope, although a magnifying glass was used.

Berthelot† compared certain specific chemical reactions caused by light and an electric current with those provoked by radium. He noted that the work is tedious on account of the small quantities of radium to be used and the necessity for working in glass envelopes, which absorb part of the rays and in certain cases probably the most efficient portion. M. and Mme. Curie noted that various chemical effects produced by radiations from radium were similar to light. Becquerel‡ extended the examination with a sealed glass tube enveloped in aluminum foil. Glew§ gives a random list of substances which fluoresce, and some which do not, when submitted to the action of radium bromide within a glass container and surrounded by black paper. Crookes' spinthariscope‖ is an instrument for showing the luminescent effect produced upon a Sidot's blende screen by exposed radium salts. Elster and Geitel¶ independently observed the luminosity produced by the bombardment of radium "electrons" and showed the difference between phosphorescence produced by emanation and that produced by illumination. We have not, however, learned of any experiments where pulverized materials, mineral and chemical preparations, have been mixed directly with radium-barium compounds of different composition and activities in this manner.

We** have mixed pulverized chlorophane, willemite, zinc oxide (made by the French process), zinc sulphide, and

* The sources of these oxides are given in a previous paper. This Journal, Dec., 1903, p. 465.

† Compt. Rend., cxxxiii, 659.

‡ Compt. Rend., cxxxiii, 709 (1901).

§ Nature, July 2, p. 3, 1903.

‖ Chem. News, lxxxvii, 241.

¶ Physik. Zeitschr., iv, 15, 439.

** Trans. N. Y. Acad. Sci., Oct. 6, 1903.

kunzite,* with radium-barium chloride (240 activity) and carbonate (100 and 40 activities). All gave good luminosity.

It may be recalled that in a previous communication it was stated that of the oxides mentioned above when submitted to the action of ultra-violet light, only two of them became phosphorescent, namely, zirconium and thorium dioxides.

Further, it should be noted that one of these oxides is not radio-active, namely, zirconium dioxide, while thorium dioxide is; also that uranium oxide, which is radio-active, does not respond to the ultra-violet light. *Is it possible that we have a common constituent in zirconium and thorium that differs from the others and still is different from the constituent which makes uranium responsive?*

It has been frequently noted and is well known that chlorophane is extremely sensitive to ethereal or mechanical stresses, giving evidence of such sensitiveness by luminosity. We have learned, as will be published later in full, that chlorophane contains yttrium and ytterbium. Neither of these oxides responds either to the ultra-violet light or the radium; hence we cannot attribute the sensitiveness of chlorophane to their presence. *Is it not possible that we have here, as well as in willemite and the other zinc compounds mentioned, a new substance, perhaps elementary, which acts as a radium foil, as it were?*

We propose to carry on further the investigation of these matters.

* This contains zinc as will appear shortly in the completed analysis by one of us (B) and Davis.

ART. VII.—*On the Numbers of Nuclei produced by Shaking Different Liquids and Allied Results;* by C. BARUS.

1. IN my report on the nucleus,* I showed that the number produced in a given mode of comminution was least in pure water, greater in dilute organic solutions and still greater in dilute inorganic solutions, all of the same strength. Results were also given for other solvents than water, in particular for benzol; but I was unable to reduce the data to the same scale as for aqueous solvents, as the data needed for the reductions were not at hand. I have since found that the method of Wilson and Thomson† lends itself to benzol and have, therefore, computed the data over again as shown in Table I.

The pressure reduction used to effect the condensations was throughout $\delta p = 16^{cm}$. Hence at about 20° the adiabatic fall of temperature in case of a benzol-air medium should be as far as $-10{\cdot}2°$, the rise of temperature thereafter (due to condensed liquid) to $11{\cdot}3°$, and consequently the liquid benzol precipitated per cubic centimeter $m = 30{\cdot}4 \times 10^{-6}$ grams. The goniometer factor was $a = {\cdot}0031 = d\,s$, being the product of the diameter d of the fog particle and the apertures of the corona. Hence the number of nuclei per cubic centimeter is finally $n = 1{\cdot}95\,(10\,s)^3$, all the coronas in question being normal, excessively intense and brilliant.

This may be compared with water. The corresponding temperature reduction of the water air medium is to $-7{\cdot}6°$, the rise of temperature due to the ensuing condensation as far as $9{\cdot}5°$, so that $m = 4{\cdot}5 \times 10^{-6}$ grams per cub. cm., almost 7 times smaller than the corresponding datum for benzol. When the same goniometer as above is used, therefore, $n = {\cdot}29\,(10\,s)^3$.

TABLE I.—Number of nuclei produced by identically shaking solutions of one per cent concentrations.

Solution, etc.	Nuclei per cm³ of air.	Solutes.
Pure water	130	--------
Organic bodies in water	630	sucrose, glucose, glycerin, urea, tartaric acid
Inorganic salts in water	1260	Na_2SO_4 $CaCl_2$ $Ca2NO_3$ K_2SO_4 $FeCl_3$ Al_2NO_3 alum $NaCl$ $Fe3NO_3$ Na_3PO_4 HCl H_4NNO_3
Naphthalene in benzol.	3500	
Paraffine in benzol	5000	

* Smithsonian Contrib., No. 1373, chap. v, 1893.
† Phil. Mag. (5), xlvi, p. 538, 1898.

The curious result thus appears that the number of nuclei produced by a definite amount of shaking is least for water, about 5 times greater for dilute organic solutions in water, about 10 times greater for dilute inorganic solutions in water, and about 30 to 40 times greater for dilute solutions of non-conductors like naphthalene and paraffine in benzol. It is difficult to even conjecture a reason for this behavior.

2. *Coronas in general.*—The coronas in benzol for the same pressure differences as above are all normal even if nucleation from sulphur, phosphorus, etc., is introduced. From the slow diffusion of the vapor they soon become distorted during successive exhaustions unless the vessel is shaken between each. It is interesting to show, however, that in spite of the normal coronas, the high initial nucleation is fully accounted for. To do this I shall select a series of observations for coronas in benzol vapor at random (l. c., p. 56). Sulphur nuclei were used and the vessel shaken between observations. The table gives the results.

TABLE II.—Coronas in benzol vapor, shaken between observations. $\delta p = 18^{cm}$; $n = 6m/\pi d^3$; $m = 33 \times 10^{-6} g$ per cm^3; $d = \cdot 00144/s$.

Exhaustion No.	$d \times 10^3$ observed. cm.	$d \times 10^3$ computed. cm.	$n \times 10^{-3}$ computed.
0	Fog without coronas	·2	6,800
1	" " "	·3	3,200
2	" " "	·4	1,400
3	" " "	·5	610
4	" " "	·6	270
5	·8	·8	120
6	1·0	1·1	52
7	1·3	1·4	23
8	1·8	1·8	10
9	2·6	2·4	4·4
10	3·7	3·2	1·9
11	4·2	4·2	·85

Computed exponentially the initial nucleation would run up into the millions. The observations are not, however, in keeping with such a locus and conform more closely to $1 = d(1/d_0 - z\sigma/a)$ or $s = s_0 - \sigma z$ and $ds = a$. For present purposes this is near enough. I shall, therefore, lay off the aperture s as a linear function of the number of the exhaustion z, for which the observations show per unit of z, in case of sulphur nuclei, $\delta s = \cdot 28$ and in case of punk nuclei $\delta s = \cdot 19$. The initial aperture computed herefrom as the mean of six series in each of which the nucleation was introduced independently, are for sulphur, $s_0 = 3 \cdot 4$ and for punk $s_0 = 2 \cdot 2$. Hence $n_0 = 840{,}000$ in the former case and $n_0 = 230{,}000$ in the latter.

Since the pressure ratio was in each case 1·36, the nuclei in the influx air passing over burning sulphur or glowing punk must have been 3·8 times more numerous. Thus there were nearly 3 million sulphur nuclei and nearly 900,000 punk nuclei per cubic centimeter in the laden air currents entering the condensation chamber.

I shall show elsewhere that the equation applicable to the present experiments is

$$n_z = n_Z 10^{(z-Z)\log y} \prod_Z^{z-1} (1 - S/s^2),$$

where n_Z is the initial nucleation, y the volume ratio on exhaustion, z the number of the exhaustion and S an appropriate subsidence constant. The function Π is a product of the terms

$$(1 - S/s^2_Z)\ (1 - S/s^2_{Z+1})\ \ldots\ (1 - S/s^2_{z-1})$$

so that Z is the number of the exhaustion in which the first corona is seen and $\Pi = 1$. When the particles are as large as is the case for benzol the subsidence function is of prevailing importance and masks the exponential function, as all the observations for benzol show. I have carried this method out for water vapor, obtaining consistent results throughout. The present observations for benzol are scarcely systematic enough to make worth while to compute S, and the experiments should be such in which the diffusion and homogeneity of vapor is ensured by continued rotation of the vessel rather than by shaking. But there can be no doubt that with proper precautions in this respect, the number of nuclei furnished per cubic centimeter by any given nucleator can be determined with benzol vapor, as the coronas are all normal even for large values of nucleation, with certainty.

3. *Axial colors.*—It is because of the relatively great number of relatively large particles in case of benzol and similar hydrocarbon vapors, that the axial colors are seen and may be traced into much higher orders than is the case with water vapor. The yellows, browns, etc., of the first order may be easily obtained with the steam jet though they can not be produced in the condensation chamber by any means whatever. The subsequent violets, blues, etc., however, are here distinctly seen as far as the orange-red of the second order, after which the admixture of white light makes recognition of color more and more difficult. With hydrocarbon liquids like gasolene, benzine, etc., the axial colors are seen much farther along the series even through a short column, and they are intense in the drum. The difficulty in observation encountered is due to the slow diffusion and consequent absence of homogeneous vapor.

I hope, however, by keeping the drum in rotation around the axis of vision as already suggested to counteract this discrepancy and correspondingly to prolong the series.

4. *Carbon disulphide.*—The vapor of this reagent is another in which coarse normal coronas usually appear. The endeavor to produce the higher coronas with sulphur, punk or air nuclei fails if the pressure differences are of the same order as those used for water. Particles of the fog are usually about $d = {\cdot}001^{cm}$ in diameter for strong nucleation, and the dense coronas produced on shaking showed diameters of the order of $d = {\cdot}0015$ under the given conditions of exhaustion. Relatively large coronas were obtained with nuclei which apparently rise from this reagent spontaneously. Thus after about 2 hours $d = {\cdot}002$, after 6 to 15 hours $d = {\cdot}0012^{cm}$ was observed. The fact that the coronas increase in size in the lapse of time suggests other explanation than the slow diffusion of vapor or the difficulty in keeping it uniformly saturated when successive exhaustions are made. For in this case coronas would decrease and the size of the particles increase, whereas the reverse is observed.

The computation of the number of nuclei per cubic centimeter for carbon disulphide is more precarious in view of the high vapor pressures and the deficiency of data applying throughout the range of temperature involved. For the case of a pressure decrement of $\delta p = 18^{cm}$ from 76^{cm}, and at 20°, the adiabatic fall of temperature would be as far as —34°, the rise therafter due to condensed liquid as far as 5°. This implies 53×10^{-6} grams of fog particles per cubic centimeter, whence with the above goniometer the number of nuclei per cubic centimeter would be $n = 34\ (10\ s)^3 = {\cdot}10/(10\ d)^3$.

The coronas obtained by spontaneous nucleation thus correspond to $n = 13{,}000$ after three hours and $n = 50{,}000$ after 6 hours or more. Finally punk nuclei after two or three exhaustions with shaking were still present to the number of $n = 75{,}000$ per cubic centimeter.

Brown University, Providence, R. I.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Titrations with Potassium Iodate.* — A new application of iodates in volumetric analysis has been devised by Launcelot W. Andrews. This depends upon the fact that in the presence of a great excess of hydrochloric acid the reaction

$$HIO_3 + 2HI + 3HCl = 3ICl + 3H_2O$$

takes place, and upon the fact that while iodine itself colors an immiscible solvent, such as chloroform or carbon tetrachloride, the iodine monochloride imparts no color to the solvent, although it gives a bright yellow color to the hydrochloric acid solution. Therefore, the iodine in an iodide may be accurately determined by placing the solution of the iodide in a glass-stoppered bottle, adding about an equal volume of concentrated hydrochloric acid and about 5^{cc} of chloroform, and then running in a standard solution of potassium iodate until, after shaking, the chloroform becomes colorless. The end-reaction is exceedingly sharp, while ferric and cupric salts, oxalic acid and small quantities of bromides do not interfere with the operation. The process may be used also for the determination of free iodine, in which case the following reaction takes place:

$$HIO_3 + 4I + 5HCl = 5ICl + 3H_2O.$$

It may be used in determining chromates, if a titrated solution of potassium iodide is at hand. In this case an excess of the iodide is added to the chromate solution, and the excess is determined by the addition of iodate solution. Chlorates can be determined in a similar manner, but here an amount of pure fuming hydrochloric acid at least one-third greater than the volume of the solution should be added, and the bottle should be allowed to stand for 15 minutes before titrating with potassium iodate. Solutions of arsenious acid or chloride can be titrated in the same way as iodides. Here, however, the amount of actual hydrochloric acid in the liquid must be kept between 15 and 25 per cent. The determination of antimony is precisely like that of arsenic. Since copper as a cupric salt does not interfere, it is possible to determine arsenious acid in Paris green without a preliminary separation. Ferrous salts can be titrated in exactly the same way as iodides, but here the end reaction appears to lack sharpness, although test analyses with ammoninm-ferrous sulphate gave very satisfactory results.

The method promises to be an important addition to our volumetric processes, since nearly all of the analyses usually made by Bunsen's method of distillation can be made by it more easily, and also because it is applicable to some important special cases. —*Jour. Amer. Chem. Soc.*, xxv, 756. H. L. W.

2. *The Oxidation of Platinum.* — It has been generally supposed, up to the present time, that metallic platinum is incapable of being oxidized by the action of air or oxygen, and that platinum-black consists of a mechanical mixture of pure platinum with condensed oxygen. The latter view does not appear to be in accordance with general chemical principles, but it has held its place in chemical literature, probably on account of the high authority of Liebig and Döbereiner who advocated it. LOTHAR WÖHLER has recently described an elaborate research in regard to the behavior of platinum with oxygen, and he has shown conclusively that this metal is susceptible to oxidation. The presence of an oxide in platinum-black was shown by the fact that iodine was set free by it from potassium iodide. It was found that platinum-black, by being heated for a long time in contact with oxygen, took up the latter to the extent of 1·92 per cent at 100° and 2·35 per cent at 300°, although the limit of oxidation was not reached. It was found that oxidized platinum-black was soluble in dilute hydrochloric acid to the extent of from 10 to 18 per cent of its platinum, and it was found that precipitated platinous hydroxide was entirely analogous in many reactions to the oxidized platinum-black. Moreover, grey platinum sponge, by long heating in oxygen at 420–450°, was converted to the extent of 40 per cent into a black powder which was found to be platinous oxide, although the limit of oxidation was not reached, and even the oxidation of platinum foil was found to be possible, as was shown by its increase in weight and very marked change in color.

The results of this investigation are important, since they furnish a satisfactory explanation of much of the chemical behavior of finely divided platinum.—*Berichte*, xxxvi, 3475.

H. L. W.

3. *The Production of High Vacua for Distillation.* — Chemical distillations under diminished pressure are commonly made by use of the water-jet pump, but the nearest approach to a vacuum obtainable with this apparatus is from 8 to 15^{mm} pressure, according to the temperature of the water. For lower pressures mercury pumps or other air-pumps may be used, but as these are not always available, ERNST ERDMANN has devised a process for the purpose which depends upon the low vapor tension of carbon dioxide at the temperature of liquid air. The apparatus to be used for distillation is first exhausted by means of the water pump to 30 or 35^{mm}, then, by means of a suitable connection provided with a glass stop-cock, carbon dioxide produced in a Kipp generator and dried with sulphuric acid and calcium chloride is admitted until the apparatus is filled with it. The apparatus is then exhausted as before, and the filling with carbon dioxide and exhaustion are repeated three times, when a small bulb connected with the apparatus is immersed in liquid air. The pressure then sinks within a minute to less than $0·5^{mm}$, usually to 0·2 or $0·3^{mm}$. If the filling with carbon dioxide and exhaustion have been repeated a fourth time the pressure is still lower, and it has been

found that where the use of rubber stoppers and tubing is avoided it is possible to produce a cathodic vacuum by this method. The article under review states that the liquid air, a supply of which is necessary for this process, can now be purchased in London for less than 50 pf. per kg, and that it is becoming more easily obtainable in Germany.—*Berichte*, xxxvi, 3456. H. L. W.

4. *A Method of Crystallizing difficultly Soluble Substances.*—A. DE SHULTEN employs for the purpose under consideration a process which consists in mixing, very slowly, hot, dilute solutions of two substances which give the substance sought by double decomposition.

For example, a solution of 10^g of $BaCl_2 \cdot 2H_2O$ in 3 liters of water, to which are added 300^{cc} of concentrated HCl, is heated in a flask on a water-bath, and into this are allowed to fall drop by drop, at the rate of one or two drops per minute, 2 liters of a solution of sulphuric acid containing 2^g of the acid per liter. After 24 hours the first crystals of barite appear at the bottom of the flask, and they increase gradually without the formation of any precipitate. At the end of a month 8 or 9^g of barite are formed. By the same process alumina is deposited in the form of hydrargillite. The author has obtained several other artificial minerals in this way, including celestite, anglesite, haidingerite, erythrite, annabergite, and scheelite.—*Comptes Rendus*, cxxxvi, 1664. H. L. W.

5. *Fractional Distillation;* by SYDNEY YOUNG. 12mo, pp. 284. London, 1903 (Macmillan and Co.).—This book has been prepared with the hope that the solution of the difficulties which so often occur in carrying out a fractional distillation may be rendered easier, and that the value and economy of highly efficient still-heads in laboratory work may come to be more widely recognized than is generally the case at present. It is an excellent treatise on the subject, and chemists will find it interesting as well as useful. H. L. W.

6. *Elektro-Metallurgie;* von Dr. W. BORCHERS, Dritte Auflage, Zweite Abtheilung. 8vo, pp. 289 to 578. Leipsic, 1903 (S. Hirzel).—The first part of this book was noticed in this Journal about a year ago. The second part now under consideration completes the work. It treats of silver, gold, zinc, cadmium, mercury, tin, lead, bismuth, antimony, vanadium, chromium, molybdenum, tungsten, uranium, manganese and iron, as well as of carbides and silicides. The work is a very important and valuable contribution to the theoretical and practical knowledge of this rapidly-developing branch of industry. H. L. W.

7. *A New Form of Galvanometer.*—One hardly expects to find in the description of new galvanometers a radical departure from old types, yet the instrument devised by W. EINTHOVEN of the physiological laboratory of the University of Leyden justifies the title of a new galvanometer. It consists of a silvered quartz fiber of extremely small diameter, $2 \cdot 1\,\mu$ diameter, which is stretched between the poles of a magnet. When the magnetic

field is excited the filament moves out of the field and the movement is read by a microscope. The author was led to devise the instrument from a consideration of the elements which enter into the law for the normal sensitiveness of a galvanometer. It was seen that a mirror, however small, limited the possible sensitiveness. The quartz fiber was stretched between the poles of a magnet of $12 \cdot 5^{cm}$ height, which enclosed a field of from 20,000 to 23,000 c. g. s. The poles are bored in order to light the fiber and also to allow the use of a microscope. By means of a slit at right angles to the axis of this boring, it was possible to photograph the excursions of the fiber under varying currents. Photographs of these oscillations are given. The microscope employed magnified 660 times. The period of swing is very short; in a case mentioned by the author only 0·004 sec. The sensitiveness is from 100 to 200 times that of the most sensitive instrument (Panze galvanometer of Rubens) hitherto constructed. The instrument is not affected by jars and vibrations to which other galvanometers are subject, and would seem to be of great use in the detection of minute currents, or rapidly varying currents, which are studied in physiological investigations.—*Ann. der Physik*, No. 13, 1903, pp. 1059–1071. J. T.

8. *The Magnetic Properties of Systems of Corpuscles describing Circular Orbits.*—This paper by Prof. J. J. THOMSON is mathematical and not experimental. The problems discussed are:

(1) The magnetic field due to a number of negatively electrified corpuscles situated at equal intervals round the circumference of a circle and rotating in one plane with uniform velocity round its center.

(2) The effect of an external magnetic field on the motion and periods of vibration of such a system.

These problems are met with when we attempt to develop the theory that the atoms of the chemical elements are built up of large numbers of negatively electrified corpuscles revolving around the center of a sphere filled with uniform positive electrification. The mathematical analysis shows that when the velocity of the particle is small compared with V, the velocity of light, the rate at which energy radiates, diminishes very rapidly as the number of particles increases. It is also shown that a body whose atoms contain systems of rotating particles is not necessarily magnetic, and that we cannot explain the magnetic or diamagnetic properties of bodies by the supposition that the atoms consist of charged particles describing closed periodic orbits under the action of a force proportional to the distance from a fixed point. We cannot explain the magnetic properties of bodies by means of charged particles describing, without dissipation of energy, closed orbits. When there is dissipation of energy the particles may possess magnetic properties.

In discussing this point, Thomson remarks that if the energy of projection were derived from the internal energy of the atom, there would be a continual transference of energy from the atom

to the surrounding systems; this would tend to raise the temperature of the system. He proposes to test the question whether the temperature in the middle of a mass of a magnetic substance like iron, whose surface is kept at a constant temperature, differs from the temperature inside a mass of a non-magnetic substance like brass, whose surface is kept at the same temperature.—*Phil. Mag.*, Dec., 1903, pp. 673–693. J. T.

9. *Laboratory Physics.* A Student's Manual for Colleges and Scientific Schools; by D. C. MILLER. Pp. xv + 403. New York, 1903 (Ginn & Co.).—This is a book to be highly commended. The experiments given with the object of teaching manipulation are not too trivial as it is too often the case, and those given to illustrate or demonstrate principles are not too intricate or difficult for the grade of students for which the book is written. The introductory remarks on observations, errors, corrections, probable error, significant figures, graphical methods, etc., are admirably done. The book is kept within a reasonable compass by means of giving the theory of the experiments for the most part in references. In order for this method to work satisfactorily, an adequate quiz system must accompany the laboratory work. This is in line with the author's aim to make the laboratory an intimate and not a separate part of the general instruction in physics. He advises that more than half of the whole time spent on physics be given to lectures and recitations. This idea of the unity of the subject is one which the prevalence of the elective system in this country has tended to obscure. The separation between experimental and theoretical physics is intellectually vicious, though, unfortunately, often made in our colleges. Hence it is doubly a pleasure to welcome a book that aims to aid in the teaching in the laboratory of that part of theoretical physics which can advantageously be so taught; and not to teach "Experimental Physics" as if it had a separate existence.

The book closes with an adequate set of tables of physical constants, etc., though why such a useless table of trigonometric functions should be included is hard to see. L. P. W.

10. *Physical Laboratory Manual for Secondary Schools;* by S. E. COLEMAN. Pp. 234. New York, 1903 (American Book Co.).—This appears to be an excellent example of this class of manual. Seventy-seven exercises, of which about two thirds are quantitative, are outlined. Of these some forty or fifty are suggested as covering the usual ground of the laboratory courses of secondary schools, thus leaving considerable margin of choice in experiments to the teacher. The directions, as far as examined, seem to be clear and concise. The attention paid to the computation of percentage errors in data and result is especially to be commended. The main adverse criticism to be made on the book is one that applies to the majority of its class, namely, that the teaching of quantitative relations by means of equations is practically ignored. Why is mathematical reasoning, one of the most fundamental and important methods of reasoning known to physics, entirely

slighted in books like this? Such omissions cannot fail to foster in the minds of the student the false notion that in some way experimental physics has a separate existence from theoretical physics. L. P. W.

11. *Elements of Electromagnetic Theory;* by S. J. BARNETT, New York, 1903 (The Macmillan Company).—This is a systematic treatment of the elements of electromagnetic theory with its simpler non-technical applications. The English attitude of making the concepts, with which one has to deal, real physical entities by the use of "tubes" and mechanical ethers is emphasized. We note that the author uses the rational units of Heaviside. The large number of figures enliven the text and the numerous references to original memoirs and advanced treatises materially add to the value of the work for the really serious student. The closing chapters on convection and displacement currents, flux of electro-magnetic energy, and electric waves puts the student into a position to read with profit the modern theories of light and of disturbances in the ether in general. The work has long been needed and is a welcome addition to our literature on mathematical physics. E. B. W.

II. GEOLOGY AND MINERALOGY.

1. *United States Geological Survey*, C. D. WALCOTT, Director. —The following publications have recently been received:

FOLIO NO. 95. Columbia, Tenn.; by C. WILLARD HAYES and EDWARD O. ULRICH. The Columbia quadrangle is located on the western margin of the Central Basin of Tennessee and shows the topography, structure and sedimentary record of the Cincinnati arch on the western flank of which it is located. The sediments are Silurian and Carboniferous separated by a thin bed of Chattanooga shale (Devonian). Commercially this region is of great interest because of the presence of rock phosphates. Ten phosphate horizons are recognized in Ordovician and Devonian strata. The Ordovician phosphatic limestones were deposited in very shallow water and made almost wholly from phosphatic shells of mollusks, "which seem to have flourished almost to the exclusion of the more characteristic elements of the Ordovician fauna." The brown phosphate of commerce is the result of the leaching to which these rocks have been and are now subjected. The Devonian phosphate rocks are partly due to animals then living but largely to the residual mantle overlying the weathered Ordovician limestones.

The addition of a faunal chart and of a sheet illustrating the fossil fauna which appears in this folio is to be commended.

FOLIO NO. 96, Olivet, South Dakota; by J. E. TODD. The Olivet quadrangle includes part of the James River Valley and its features are those of very subdued glacial topography. With the exception of a very few small outcrops of Benton and Colorado (Cretaceous), the entire region is mantled by drift of the

Wisconsin stage. Two systems of well-marked moraines are shown. As a study of simple glaciation and of water conditions this folio occupies a unique place.

BULLETIN No. 217. Notes on the Geology of Southwestern Idaho and Southeastern Oregon; by ISRAEL C. RUSSELL. 80 pp., 18 pls., 2 figs.

Taken in connection with Bulletin No. 199 and Water Supply Paper No. 78. the publication of Professor Russell's recent work gives a fairly complete account of the general geological relations of the interesting Idaho-Oregon arid region. Malheur Lake (a water body 135 square miles in area and less than 10 ft. deep!) is not a remnant of a larger lake but is caused by a lava dam. The volcanic phenomena of this region is particularly interesting. Details of structure, of character of flows, cones, bombs, are described and illustrated. Many of the bombs were not formed by rotation in air. Besides the recent volcanics, Tertiary lake beds and lavas occur in this area.

WATER SUPPLY AND IRRIGATION PAPER No. 85. Report on Progress of Stream Measurements for the Calendar year 1902; by F. H. NEWELL. Part IV. Interior Basin, Pacific Coast and Hudson Bay Drainage. 289 pp., 2 maps.

No. 86. Storage Reservoirs on Stony Creek, California; by BURT COLE. 60 pp., 15 pls., 38 figs.

2. *New York State Museum*, F. J. H. MERRILL, Director, has recently issued the following publications:

BULLETIN No. 66. Index to Publications of the New York State Natural History Survey and the New York State Museum; by MARY ELLIS; pp. 239–653. An Index has been made to the publications of the New York Survey and related scientific organizations covering the years 1837–1902. The arrangement gives: a list of publications; author index; subject index; index to descriptions of fossils. This bulletin renders readily accessible the scientific data distributed in an apparently haphazard way through various New York reports.

MAP OF THE STATE OF NEW YORK showing surface configuration and watershed. This map, drawn on a scale of 12 miles to the inch, is especially valuable for the physiographer and for use in schools.

3. *Geology of Worcester, Mass.*; by JOSEPH H. PERRY and B. K. EMERSON. 159 pp., fully illustrated. Published by the Worcester Natural History Society.—Mr. Perry has for several years been assisting Prof. Emerson in mapping the metamorphic rocks of Worcester County under the direction of the U. S. Geological Survey and has now published part of the results of this work. Because of the nature of the region, mineralogical and petrographical descriptions constitute the greater part of the book. Geologists will be interested in the descriptions and excellent illustrations of *Lepidodendron acuminatum*, the only fossil yet found over a wide area in Massachusetts and Connecticut. The occurrence of this fossil shows the Worcester phyllite to be

of Carboniferous age and gives a starting point in geological chronology for the variable metamorphics east of the Connecticut Valley Triassic.

4. *The Paleontology and Stratigraphy of the Marine Pliocene and Pleistocene of San Pedro, California;* by RALPH ARNOLD. Mem. California Acad. Sci., vol. iii, 420 pp., 37 pls., June, 1903.—Mr. Arnold has produced an admirable monograph on the later fossil faunas of the California coast. The investigation was carried on under the supervision of Professor J. P. Smith of Leland Stanford University and is based upon the study of six large collections of the fossils discussed, 408 species of which are cited. The chief sections studied are at San Diego, San Pedro, Ventura, Santa Barbara and Lake Merced, and represent strata from 150 to 5350 feet in thickness.

The formations recognized are the Merced series, chiefly Pliocene, and the lower and upper San Pedro of Pleistocene age.

The Pliocene species are 87 in all, of which 63·1 per cent are now living at San Pedro; 18·5 per cent of the whole fauna are species living only north of San Pedro, and no species only south of that point. Of the 247 species from the lower San Pedro beds (Pleistocene), 64 per cent are living at San Pedro, 17·4 per cent only north and 3·2 per cent only south of that point.

Of the 252 species from the typical beds of the upper San Pedro (Pleistocene) 68·2 per cent are living, 6·1 per cent live only north and 14·2 per cent only south of San Pedro. From these facts the author concludes "that during the latter part of the Pliocene epoch the climate was much colder on the coast of Southern California than at the present time," p. 65; "that climatic conditions were changing from boreal toward tropical during the time of the deposition of the lower San Pedro series, but that boreal conditions still preponderated," p. 66. "The evidence offered by the upper San Pedro faunas leads to the conclusion that semitropical conditions prevailed during the deposition of this formation. The similarity of the fauna of these beds with that now living at San Pedro and the adjacent coast, makes it probable that the conditions, although more tropical than those of the present time, were not extremely tropical," p. 67.

A comparison of the Japanese with the Californian coast species, fossil and living, shows that great similarity exists between the late Tertiary and Pleistocene marine invertebrate fauna of Japan and that of the western coast of the United States; and the living faunas of the Japanese and West American coasts, though having many species in common, are not so closely related as are the upper Tertiary and Pleistocene faunas of the same region. H. S. W.

5. *Postglacial and Interglacial (?) Changes of Level at Cape Ann, Massachusetts;* by R. S. TARR. *With a Note on the Elevated Beaches;* by J. B. WOODWORTH. Bull. Mus. Comp. Zool. xlii, pp. 181–196, 13 pls.—Evidences of several kinds indicate that Cape Ann has been depressed to a level at least 40 to

60 feet lower than the present. Beds of crumpled and faulted clays overlaid by till and underlaid by gravels lie 25–30 feet above mean sea level and "there is little reason to doubt their interglacial age." Professor Woodworth finds evidences of strong wave action as high as 80 feet above the sea and concludes that marine action rather than glacial lake waters was concerned in the beach making.

6. *Latest and Lowest Pre-Iroquois Channels between Syracuse and Rome, New York*; by H. L. FAIRCHILD. 21st Report New York State Geologist, pp. 233–247, pls. 7–31.—The level water-planed stretches utilized by the New York Central R. R. from Syracuse to Rome and by the Erie Canal between Syracuse and Canastota, were formed by rivers between the ice front and the high ground on the south. The description and elaborate illustration of these channels will be appreciated by teachers of geology especially.

7. *Contributions to the Tertiary Fauna of Florida, etc.;* by W. H. DALL. Part VI, pp. xi, 1219–1654, with plates xxviii–lx. Philadelphia, October, 1903.—This volume, appearing as vol. III, Part VI of the Transactions of the Wagner Free Institute of Science of Philadelphia, forms the concluding portions of Mr. Dall's great work on the Tertiary Fauna of Florida, repeatedly noticed in this Journal. The author and the scientific public are to be alike congratulated upon the successful completion of so important a labor and no small measure of thanks are due to the Wagner Institute for its liberal support.

8. *Spinel Twins of Pyrite;* by WM. NICOL. (Communicated.)—Some time since, the writer found among a number of brilliant pyrite crystals from French Creek, Pa., bought from Ward's scientific establishment at Rochester, two small ones which were evidently "spinel twins." In size the crystals were about 2^{mm} in diameter. They were found embedded in calcite and associated with byssolite. In both cases the two twinned individuals were equally developed octahedrons showing the usual distortion, viz: flattening parallel to the twinning plane. The faces when observed on the Goldschmidt two-circle goniometer gave signal reflections with fairly good measurements, which showed without doubt that the requirements of the spinel law were complied with. In a later number of this Journal the details of the observations will be communicated. As far as I can ascertain, the spinel law, by far the most common twinning law in the regular system, has not yet been observed in the case of pyrite, therefore it may be of interest to know that its existence has been proved beyond doubt.

9. *Ramosite not a Mineral;* by LEA McI. LUQUER. (Communicated.)—The doubtful mineral Ramosite occurring in pebbles in alluvium from San Luis Potosi, Mexico, originally described by Perry in the Transactions of the American Institute of Mining Engineers in 1884 (vol. xii, 628), has been carefully reëxamined with the following results.

Sections were obtained with great difficulty on account of the extreme hardness and brittleness, but proved the material to be greenish by transmitted light, non-pleochroic and isotropic and gave no indication of crystalline structure. Irregular fracture lines were common, sometimes approaching in appearances cleavages, and many minute shot-like grains of an iron-stained decomposed mineral were noticed.

The region in which the material occurs is volcanic, and the very marked vesicular structure and conchoidal fracture would indicate a volcanic scoria. The hardness from 8–9 is unusual, but basic scorias from the Sandwich Islands and elsewhere have shown a hardness from 6–7, greater than that of ordinary obsidian. The recorded analysis, for which no great accuracy is claimed, shows:

SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	MnO_2
46·32	13·00	9·19	17·74	13·13	trace = 99·38.

corresponding rather closely to formula $R_2O_3.4RO.5SiO_2$. The material qualitatively resembles garnet, but quantitatively differs widely; thus removing the possibility of it being a kind of garnet (as suggested by Dana).

The analysis of a tachylyte from Gethurms, Germany, by Lemberg,* shows:

SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	K_2O	N_2O	Loss
45·73	12·46	20·15	8·67	3·59	4·11	5·74	0·12 = 100·57,

as low in SiO_2 as the supposed Ramosite.

The evidence, therefore, shows the material to be *not a mineral*, but a basic scoria of unusual hardness and composition.

Department of Mineralogy,
Columbia University, N. Y., Nov. 4, 1903.

10. *List of New York Mineral Localities;* by H. P. Whitlock. Bulletin 70, Mineralogy 3, New York State Museum, F. J. H. Merrill, Director. Pp. 108, Albany, 1903.—This Bulletin will be found of much value by workers in mineralogy. It gives a carefully edited list of the species which have been found at various points in the state. The places are arranged under the separate counties, and the tables indicate the method of occurrence, the mineralogical association of the specimens, etc. In addition to the general introduction, a bibliography of two hundred and thirty-one numbers is given, to which references are made in the tables.

III. Miscellaneous Scientific Intelligence.

1. *International Catalogue of Scientific Literature.*—The history and plan of the International Catalogue of Scientific Literature have been already given in this Journal (v. xiv, 317, 1902), and some of the volumes issued have been noticed (v. xv, 490, 1902). It is gratifying to be able to record the further progress

* Zeitschr., d.d. Geol., Gesell., xxxv, 570.

of this important enterprise, and the publication of an additional series of volumes of the first annual issue, that is for the year 1901. These include the following: D, CHEMISTRY, Part II, pp. 671; G, MINERALOGY, including Petrology and Crystallography, pp. 208; J, GEOGRAPHY, pp. 268; H, GEOLOGY, pp. 220; K, PALÆONTOLOGY, pp. 170; L, GENERAL BIOLOGY, pp. 144; P, PHYSICAL ANTHROPOLOGY, pp. 224; O, HUMAN ANATOMY, pp. 212; Q, PHYSIOLOGY, including Experimental Physiology, Pharmacology and Experimental Pathology, Part II, pp. 664. There is also a volume of 312 pages given to a List of Journals.

It is to be regretted that thus far no Government aid has been obtained for this great work, and hence its prosecution would have been rendered impossible in this country had it not been taken up by the Smithsonian Institution. At first only limited means were at its disposal, but beginning with July 1, 1903, a larger sum of money is devoted to it, increasing materially the force of workers. This will make it possible to carry on the work more promptly, and to fill up what omissions have occurred from January, 1901, to the present time. It is stated that this country leads in the number of subscribers, the total being ninety-six, equivalent to seventy complete sets, for which the yearly subscription is eighty-five dollars. It is highly to be desired that this relatively good showing should be much increased, as the enterprise is one of very great importance to workers in science and should have general support, particularly from the libraries.

2. *National Academy of Sciences.* — The following is a list of the papers presented at the recent meeting of the National Academy in Chicago (vol. xvi, 475).

T. C. CHAMBERLIN: Preliminary report on the Agassiz data relative to underground temperatures at the Calumet and Hecla mine.

C. E. DUTTON: The velocities of earthquake vibrations and their significance.

A. P. MATHEWS: The relation between solution tension and physiological action of the elements.

S. W. WILLISTON: On the distribution and the classification of the Plesiosaurs.

C. O. WHITMAN: The evolution of the wing-bars in pigeons.

CHAS. B. DAVENPORT: Evolution without mutation.

J. McK. CATTELL: The measurement of scientific merit.

J. STIEGLITZ: Stereoisomeric nitrogen compounds.

CHARLES BASKERVILLE: On the recent investigations of the rare earths in the laboratory of the University of North Carolina.

E. E. BARNARD: Some peculiarities of comets' tails, and their probable explanation.

EDWIN B. FROST: Stars of the Orion class.

GEORGE E. HALE: On the nature of the solar flocculi.

GEO. C. COMSTOCK: The relation of stellar magnitude to stellar distances.

A. A. MICHELSON: Spectra of imperfect gratings.

STEPHEN MOULTON BABCOCK: The relations of weight and energy.

C. S. SLICHTER: The propagation of ground water waves.

WILLIAM H. BREWER: Biographical memoir of Sereno Watson.

3. *Astronomical Observatory of Harvard College*, EDWARD C. PICKERING, Director.—Recent publications from the Harvard Observatory include the following: Annals volume XLVI, Part I,

Observations with the Meridian Photometer during the years 1899–1902 by Solon I. Bailey. Volume XLVIII, Part V, Distribution of Stars; No. VI, Meridian Circle Observations of Eros and Comparison Stars; VII, Meridian Circle Observations of Nova Persei No. 2 and Comparison Stars; VIII, Intensity of Atmospheric Lines in the Solar Spectrum. Volume LI, A Photographic Atlas of the Moon by William H. Pickering. Also Circular No. 72, Intensity of Spectral Lines and No. 73, Opposition of Eros (433) in 1905.

The Photographic Atlas of the Moon, by Professor W. H. Pickering, is a notable work, giving, as it does, the first complete representation of this kind. The work was carried on at the Observatory at Mandeville, Jamaica, beginning in 1900. The telescope employed, constructed especially for the purpose, had a 12-inch objective (30^{cms}) and a photographic focus of 135 ft. 4 inches (4125^{cms}) so that a scale of 5 seconds to 1^{mm} was obtained. The length of focus required that the tube should be fixed and the objective viewed in the movable mirror. The results are given in a series of eighty beautiful plates, each of the sixteen portions of the surface being represented for five periods between sunrise and sunset, thus exhibiting the changes in appearance due to differences in lighting. One point of interest brought out is the variation observed at different times due to varying amounts of snow and frost in certain of the craters. Variation attributed to patches of vegetation was also observed within some of the craters. For the discussion of this and other matters of interest reference must be made to the original work.

4. *Beiträge zur chemischen Physiologie*, herausgegeben von F. Hofmeister. IV Band, 1–8 Heft., 1903. Braunschweig (Vieweg und Sohn).—The student of the chemistry of the proteids will continue to find a large number of the contributions in the *Beiträge* devoted to this department of physiological research. Special reference may be made here to papers by Gamgee and his coworkers on the optical activity of various albuminous compounds. Several of the latter are found to be markedly dextrorotatory, whereas the simple proteids are known to be lævorotatory. Digestive processes and enzymes receive attention in several papers; and two sulphur compounds, taurin and cystin, which possess considerable physiological interest, are made the subject of investigations reported from Hofmeister's laboratory. In addition to these there are papers on the precipitins; on crotin and ricin; and several communications on the lymphatic tissues by Bang, in addition to briefer notes on various experimental topics. L. B. M.

Obituary.

Herbert Spencer, one of the deepest thinkers of his time, whose philosophy has had a profound influence upon the intellectual men of all nations, died on December 8 at the age of eighty-three years.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. VIII.—*On the Properties of a Radio-active Gas found in the Soil and Water near New Haven;* by H. A. BUMSTEAD and L. P. WHEELER.

IN the October number of this Journal, the writers published a brief note concerning a radio-active gas which had been found in the surface water near New Haven, in the course of some experiments which had been undertaken at the request of Professor J. J. Thomson. It was stated that the gas obtained from water had the same properties as that which was drawn from a few feet below the surface of the ground; and that both these gases, so far as the experiments had gone at that time, seemed to be identical with the gaseous emanation from radium discovered by Dorn. The purpose of the following investigation was a more careful and direct comparison of these "natural" radio-active gases with the radium emanation, in order to find out whether they contained a small proportion of some other active constituent.

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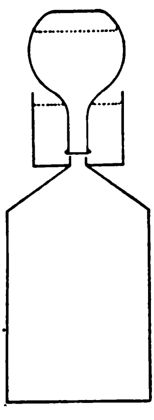

As in Professor Thomson's experiments, the gas was obtained from the water by boiling and, as it was, at best, rather feebly radio-active, it was desirable to prevent its dilution with air as much as possible. The method finally used is sufficiently indicated in fig. 1, and proved to be very convenient. It was suggested by Professor W. G. Mixter, to whom we are also indebted for several other valuable suggestions and for many kindnesses. The earlier tests of the gas were made by means

of a gold-leaf electroscope of C. T. R. Wilson's pattern, in which the leaf is supported by means of a sulphur bead from a rod kept charged to a potential at least as high as that of the leaf; so that any leak of electricity from the leaf must be through the gas and not over the support. A number of control experiments showed that the observed activity was not due to the vessels or drying tubes used, nor to the city supply pipes through which the water reached the laboratory; and the fact that water, once boiled, did not recover to any appreciable extent its power to give off a radio-active gas when left to stand, either stoppered or unstoppered, for two weeks showed that the presence of the gas was not due to contact with the air, nor to a dissolved, or suspended, radio-active solid. The latter conclusion was strengthened by our inability to find any evidence of radio-activity in the solid residue left on evaporating the water. As rain water does not contain a radio-active gas (although it does contain an active solid residue), the only hypothesis which seemed to be left to account for the presence of the gas in this surface water was that the water had come in contact with the gas in its passage through the ground and had dissolved some of it. Accordingly a piece of gas-pipe was driven about 1·5 meters into the earth and its top connected by a rubber tube to a flask filled with water; on allowing the water to run out, the flask became filled with the gas from under ground which was then introduced into the electroscope and tested as before. It proved to be much more active than the gas from water (three or four times for equal volumes) and as it was very easily obtainable in as large quantities as one wished, it was much more convenient to work with.

In order to compare it with the water-gas the rate of decay of the activity of both gases was observed. For this purpose an electroscope was made as nearly air-tight as possible by the use of solder, sealing-wax and asphaltum varnish, and by regrinding the brass cocks with which it was provided; after some difficulty it was made so tight that, upon being partially exhausted, it would lose less than one-half per cent of its exhaustion in 24 hours. When either gas was introduced into this electroscope, an initial rise of activity occurred lasting for about 0·1 day, followed by a regular decay according to an exponential law in which the activity fell to one-half its value in about four days. The curves for the water-gas and for the earth-gas were indistinguishable when reduced to the same scale; one of them is given in fig. 2. During the initial rise, observations of the leak were made as rapidly as possible, and afterward once or twice a day for about two weeks. As the sensitiveness of the gold leaf varied slightly from day to day,

it was tested after each reading by changing the applied potential by 10, 20, and 30 volts and noting the change in deflection; the readings were then reduced to a standard sensitiveness. We are indebted to Mr. H. M. Dadourian for his assistance in making these numerous and somewhat tedious observations.

The resemblance of this gas to the emanation from radium, in respect to the period of initial rise of activity (which is due to the deposition upon the walls of the electroscope of "induced" or "excited" activity) and also in respect to the

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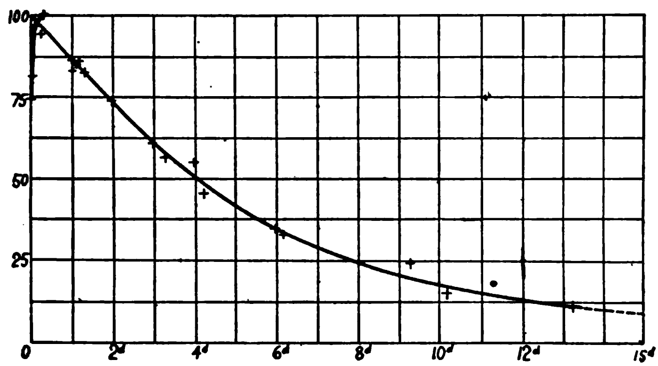

rate at which the activity of the gas itself decays, is so close that we could not hope to detect any differences between the two by means of observations with the electroscope. Accordingly, we had recourse to observations with a quadrant electrometer, and during the autumn, the earth-gas was directly compared by means of the same apparatus with the radium emanation, with regard to the rise of excited activity, the decay of the activity of the gas itself, and the rate of diffusion through a porous plate of unglazed porcelain. The electrometer used was of special construction, made after our design by Mr. L. J. Barrett, mechanician of the Sheffield Scientific School; it proved to be very steady and convenient for the present purpose, and may perhaps be described later, after its behavior under varied conditions has been more fully investigated. When the needle was suspended by a quartz fiber of very moderate thinness, the sensitiveness with 100 volts on the needle was about 250^{cm} per volt, the scale being one meter distant from the mirror. As this was sufficient for our present needs, no attempt to increase it by using a finer suspension was made, particularly as we wished to make observations, in some cases, in as rapid succession as possible and a very large period of the needle was, therefore, undesirable.

A cylindrical condenser (fig. 3), 37^{cm} high and $12{\cdot}5^{cm}$ in diameter, was made of heavy galvanized sheet-iron with rings of planished brass, A, and A′, soldered to flanges at top and bottom; at the top, the guard plate, B, rested upon a rubber gasket and was bolted to A by eight small bolts provided with ebonite bushings so that the cylinder was insulated from B, which was kept earthed. The central rod, C, passed through an ebonite collar, D, and the joints about the collar were carefully made tight by sealing-wax. At the bottom, the brass plate, E, was similarly bolted to A′ with a gasket between, but no bushings were needed in this case, and the heads of the bolts were

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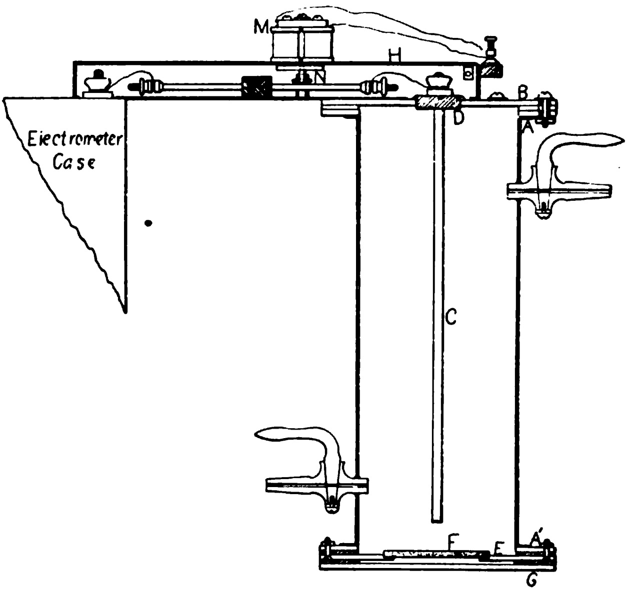

counter-sunk in the bottom surface of E; this plate had a hole in the middle, and above it the porous plate, F, was fastened with sealing-wax. Another plate, G, also provided with a gasket, was clamped below this by eight small iron screw clamps, so that it could be easily removed at any time and the porous plate exposed. The connection to the electrometer was a brass rod supported by ebonite in a rectangular brass box, H, with a hinged lid; this box rested on the guard plate, B, and on the case of the electrometer, and two holes in its bottom admitted the binding screws of rod in the cylinder and of the electrometer. Ordinarily the rod and pair of quadrants connected to it were earthed by N, which was hinged to the box and rested

on the connecting rod; by means of the little electromagnet, M, fastened to the lid of the box, N could be lifted off the rod and the quadrants could thus be insulated without the slightest jar. The short-circuiting contact was made of the same piece of brass on both sides, was small in area, and the distance moved was short; there was thus no trouble from contact potential differences. A small hole through the brass box, opposite the binding screw of the electrometer, enabled one to test the sensitiveness of the electrometer from time to time. When the gaskets were well greased with stiff mutton-tallow, the cylinder retained a pressure in excess of that of the atmosphere without perceptible diminution in twenty-four hours.

The gas to be tested was put into the cylinder and readings were made as rapidly as possible during the rise of the induced activity. After the ionization had reached a steady value, the gas was allowed to stand in the cylinder for several days, and readings were taken from time to time to determine the rate of decay of the activity of the gas; as this change was slow, the average of four readings was taken at each observation. Finally the lower plate was removed and the gas allowed to diffuse through the porous plate, readings being taken as rapidly as possible in the meanwhile. From all these readings the leak due to the so-called spontaneous ionization of the air in the cylinder was always subtracted. The potential applied to the cylinder (90 volts) was more than enough to give the saturation current in all cases. The radium emanation used was obtained by bubbling air through a solution containing 0·1 gram of the very impure radium bromide prepared a year or two ago by De Haen; its activity is about 1000 times that of uranium, so that the solution contained probably less than 0·1 milligram of radium. Three small bubbles drawn through this into the cylinder (perhaps a fifth of a cubic centimeter) caused an ionization about six times as great as 1½ liters of the earth-gas; the chief difficulty with the emanation was to get a small enough quantity into the cylinder.

Comparison of the Rates of Decay.

If we assume the exponential law of decay of the radioactivity $I=I_0e^{-\kappa t}$, the constant κ may be determined from any two observations (or two sets of four observations) taken at different times after the excited activity has ceased to rise. Several such determinations were made for the earth-gas and for the radium emanation and are given in the following tables; t in the formula is measured in hours.

It will be seen that the agreement is well within the limits of accuracy of the experiments. This constant for the radium

Earth-Gas.		Radium Emanation.	
Interval in hours.	κ.	Interval in hours.	κ.
19·31	0·00784	20·00	0·00703
24·32	0·00702	23·31	0·00739
43·63	0·00738	22·61	0·00787
		65·93	0·00745
Av.	0·00741 ± ·00016	Av.	0·00744 ± ·00012

emanation has been determined by P. Curie* and by Rutherford and Soddy† and, when reduced to the hour as the unit of time, the value obtained by Curie is 0·00724, while Rutherford and Soddy obtained 0·00778. Curie's measurements were made with the emanation in a sealed glass tube, and there could thus have been no acceleration of the apparent rate of decay by escape of the gas. The lower value obtained by us would be accounted for if one-half per cent of the emanation leaked from the cylinder in twenty-four hours. Such a lack of tightness is by no means impossible. Rutherford and Soddy's experiments were made with emanation stored in a gas-holder and drawn off from time to time for testing; a slightly greater rate of leak from their gas-holder might account for the higher value of κ obtained by them.

The Rise of the Excited Activity.

It has been observed by Rutherford that the excited activity due to the radium emanation does not decay according to a simple exponential law, and this we find to be the case also with the excited activity due to the earth-gas. The most practicable method of comparing the two seems therefore to be to reduce the measurements on the two gases to the same scale and to plot a curve for each. Two such curves are found in figs. 4 and 5.

In the reduction to the same scale, the mean of the last four observations has been taken as 100. The following tables give the actual measurements and the plotting scale:

Earth-Gas.

Time in minutes.	Observed ionization.	Plotting Scale.	Time in minutes.	Observed ionization.	Plotting Scale.
3·5	1·98	59·3	92·0	3·21	96·1
12·0	2·28	68·3	102·0	3·08	92·2
20·0	2·49	74·6	121·5	3·42	102·4
26·4	2·62	78·4	139·5	3·35	100·3
33·0	2·60	77·9	223·5	3·36	100·6
42·0	2·75	82·3	240·5	3·36	100·6
62·0	2·86	85·6	273·5	3·21	96·1
76·0	3·05	91·3	284·5	3·43	102·7

* P. Curie, C. R. cxxxv, p. 857, 1902.

† Rutherford and Soddy, Phil. Mag. (6), v, p. 445, 1903.

RADIUM EMANATION.

Time in minutes.	Observed ionization.	Plotting Scale.	Time in minutes.	Observed ionization.	Plotting Scale.
3·0	11·23	52·9	90·75	20·28	95·5
8·1	11·66	54·9	100·75	20·17	95·0
12·75	14·98	70·5	105·75	21·18	99·7
16·75	14·88	70·1	110·75	21·68	102·1
20·75	15·82	74·5	115·75	21·12	99·5
25·75	16·16	76·1	120·75	21·12	99·4
30·75	17·20	81·0	125·75	20·92	98·5
37·75	16·87	79·4	135·75	21·52	101·3
42·75	17·68	83·3	145·75	21·45	101·0
47·75	17·70	83·4	205·75	20·52	96·6
52·75	18·05	85·0	220·75	22·18	104·5
57·75	18·58	87·5	268·75	18·78	88·4
62·75	18·88	88·9	278·75	21·44	101·0
69·75	19·32	91·0	282·75	21·25	100·0
76·75	20·10	94·7	287·75	21·35	100·5
82·75	20·18	95·0	292·75	20·92	98·5

The following values taken from the plotted curve will give an idea of the agreement between the behavior of the two gases:

RISE OF EXCITED ACTIVITY.

Time in minutes.	Earth-Gas.	Radium Emanation.
20	74·6	74·4
40	81·0	81·9
60	86·6	87·9
80	91·6	93·4
100	96·0	97·5

The earlier part of the curves in figs. 4 and 5 ($t < 20$ min.) can not be very accurate. It took about two minutes to introduce the earth-gas, and to make the two experiments as nearly alike as possible the same time was consumed in admitting the radium emanation; the zero of the time scale in the curve is the middle of this interval. Few observations could be taken and the curve is so steep that small errors have a great effect upon the point where the curve cuts the axis. Moreover, the results of the diffusion experiment cannot be reconciled with so small a value of the initial activity of the gas, as will be seen; and a special experiment in which radium emanation was introduced rapidly indicated that the initial activity was between 50 and 60 per cent of the final activity. But the question could not be decided very positively with our apparatus, since the slowness of the return of the needle to its zero did not permit readings to be taken in very rapid succession.

Diffusion through a Porous Plate.

Figures 6 and 7 exhibit the results obtained when the bottom plate was removed and the gas allowed to diffuse through the

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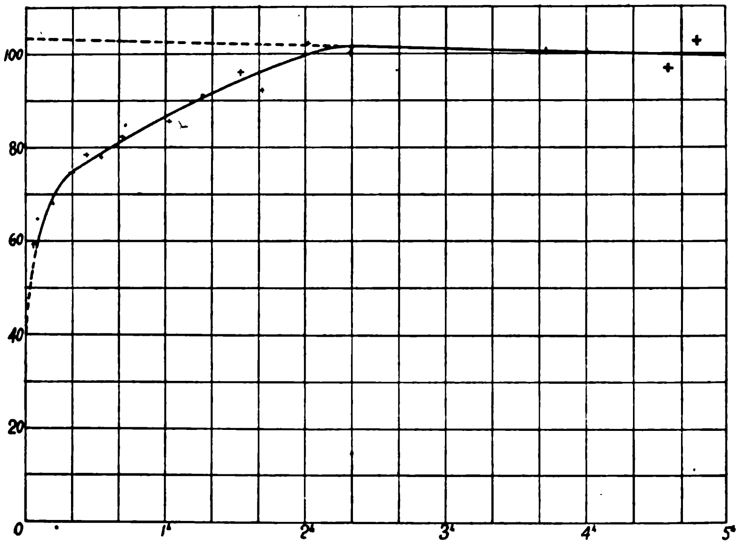

Excited activity; earth-gas.

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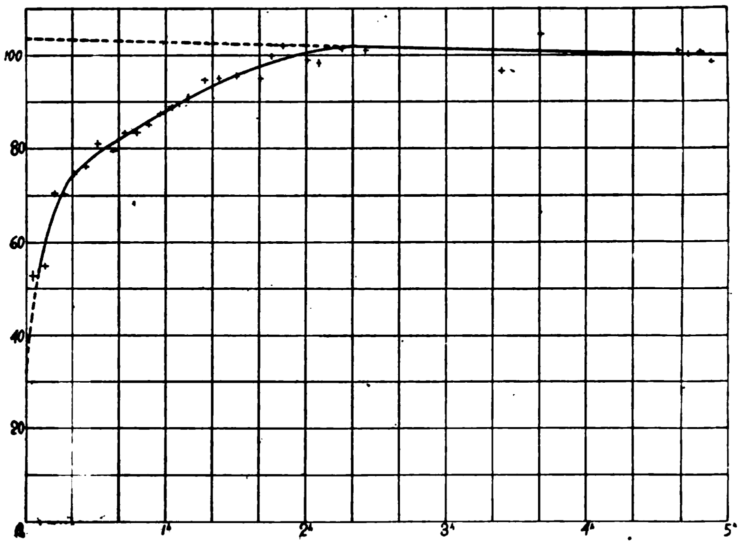

Excited activity; radium emanation.

porous plate; the time is counted from the removal of the plate. As before, the readings are reduced to the same scale, the mean of four readings just before the plate was removed being taken as 100.

EARTH-GAS.

Time in minutes.	Observed ionization.	Plotting Scale.	Time in minutes.	Observed ionization.	Plotting Scale.
0·0	2·81	100·	79·5	1·62	57·7
2·5	2·81	100·	100·5	1·52	54·1
8·0	2·68	95·4	115·5	1·26	44·9
13·0	2·70	96·1	130·5	1·12	39·9
18·0	2·60	92·5	145·5	0·93	33·1
24·0	2·42	86·1	160·5	0·82	29·2
30·5	2·39	85·1	175·5	0·67	23·8
40·5	2·28	81·1	190·5	0·59	21·0
50·5	2·06	73·3	205·5	0·49	17·4
60·5	2·00	71·2			

RADIUM EMANATION.

Time in minutes.	Observed ionization.	Plotting Scale.	Time in minutes.	Observed ionization.	Plotting Scale.
0·0	12·98	100·	59·0	8·92	68·7
4·0	12·43	95 8	64·0	8·32	64·1
8·0	12·08	93·1	69·0	7·26	55·9
11·0	12·20	94·0	74·0	8·04	61·9
17·0	11·47	88·4	102·0	6·38	49·1
21·0	11·26	86·7	110·0	5·52	42·5
26·0	10·99	84·7	115·0	5·72	44·1
31·0	10·61	81·7	119·0	5·28	40·7
37·0	10·44	80·4	226·0	1·84	14·2
50·0	9·34	71·9	230·0	1·72	13·3
54·0	9·14	70·4	235·0	1·64	12·6

The following table taken from the curves gives a comparison of the two gases:

DIFFUSION.

Time in minutes.	Earth-Gas.	Radium Emanation.
20	90·	87·6
40	80·2	76·6
60	70·6	66·0
80	60·5	56·9
100	51·8	48·5
120	43·6	41·2
140	36·0	34·6
160	29·4	28·8
180	23.8	23·7
200	18·9	19·3
220	[14·5]*	15·8
240	[11·0]*	12·0

* Extrapolated.

The agreement is not altogether satisfactory, but the character of the differences would seem to show that they are due to

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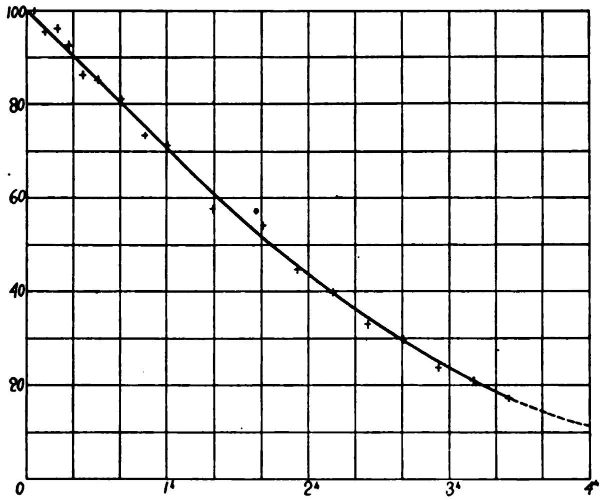

Diffusion of earth-gas.

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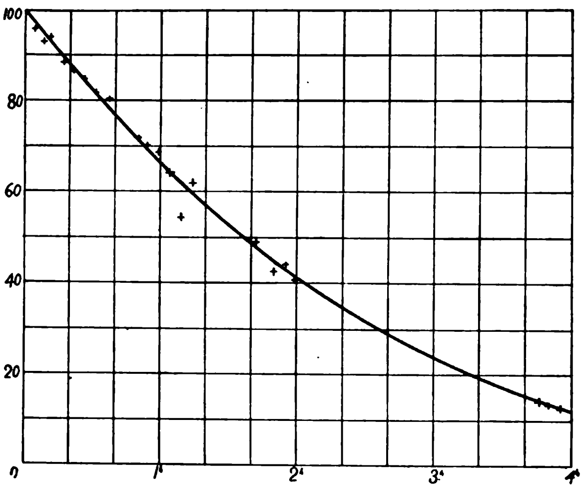

Diffusion of radium emanation.

experimental errors and not to differences in the gases. In the earlier portion of the experiments the earth-gas appears to

diffuse more slowly than the radium emanation and later it diffuses more rapidly. It is difficult to see how this could be the effect of an admixture of either a heavier or a lighter radio-active gas; and the close agreement between the total amounts, diffusing out in four hours (89 per cent and 88 per cent, respectively), together with the close similarity in the rates of decay and of the production of induced activity, show that if any other radio-active constituent is present in the ground air it must be in very small proportion.

Density of the Radium Emanation.

The observations already recorded afford a value of the density of the gas (assuming that Graham's law may be applied) provided the rate of diffusion of a gas of known density through the porous plate is determined. For this purpose carbon dioxide was introduced into the cylinder, allowed to stand until thoroughly mixed with what air remained, and the amount determined by drawing a certain fraction into a burette and absorbing with caustic soda. The porous plate was then exposed for 10 or 15 minutes and the bottom plate again clamped on; after allowing time for thorough mixture, the amount of CO_2 was again determined. Three such observations, with different times of diffusion, gave the following values for μ_1, in the formula $\rho=\rho_0 e^{-\mu_1 t}$ (t measured in hours):

1·18
1·15
1·15

———

1·16

In the diffusion experiments with the radio-active gas, if it were not for the presence of the induced activity, the curves, figs. 6 and 7, might be expected to be exponential and it would be a simple matter to obtain the corresponding constant, μ, for the radium emanation; but the effect of the induced activity must be taken into account, and this is the more difficult since its rise and decay is not susceptible of a simple mathematical expression. In fact, as Rutherford has pointed out, there are probably two or three different kinds of induced activity, in the case of radium, each being produced and decaying at a different rate. In order to make the calculation somewhat more manageable, it is assumed in what follows that the rise and decay of the induced activity does follow the exponential law; it will be seen in the outcome that this assumption cannot cause a very serious error in the determination of the diffusion constant.

Let

A = ionization produced by the gas at any instant.
E = " " " excited activity.
I = observed ionization.
So that I = A + E.

As a result of the regular decay of the activity of the gas itself we have

$$A = A_0 e^{-\kappa t}$$

Assuming that we have only one kind of excited activity, its rate of production is proportional to the quantity of gas present, i. e. to A; and its rate of decay is proportional to E, so that

$$\frac{dE}{dt} = aA_0 e^{-\kappa t} - \lambda E \tag{1}$$

Taking $t = 0$ as the time when the gas is introduced into the cylinder, the solution of this equation is

$$E = \frac{aA_0}{\lambda - \kappa}\left(e^{-\kappa t} - e^{-\lambda t}\right)$$

and the total observed effect is

$$I = A_0\left\{\left(1 + \frac{a}{\lambda - \kappa}\right)e^{-\kappa t} - \frac{a}{\lambda - \kappa}e^{-\lambda t}\right\} \tag{2}$$

As we have seen, $\kappa = 0 \cdot 0074$ when t is measured in hours, and $\lambda = 1 \cdot 36$ gives an exponential rise of excited activity not greatly different from that observed in figs. 4 and 5; so that during the first two or three hours $e^{-\kappa t}$ is nearly equal to unity, and we have approximately

$$I = A_0\left\{1 + \frac{a}{\lambda - \kappa}\left(1 - e^{-\lambda t}\right)\right\} \tag{2'}$$

The curve expressed by (2) differs from (2′) in that its asymptote is not a horizontal straight line but the curve,

$$A_0\left(1 + \frac{a}{\lambda - \kappa}\right)e^{-\kappa t};$$

and within the time considered this is sensibly an inclined straight line which is shown in figs. 4 and 5; $\frac{a}{\lambda - \kappa}$ is the ratio of the excited activity, after equilibrium has been attained, to the activity of the gas.

After three or four hours $e^{-\lambda t}$ is negligible in comparison with $e^{-\kappa t}$ so that we have sensibly

$$I = A_0\left(1 + \frac{a}{\lambda - \kappa}\right)e^{-\kappa t} \tag{3}$$

and this justifies the determination of κ by the method pursued above, without regard to the induced activity.

In discussing the diffusion experiment, it is convenient to take the initial instant ($t=0$) as that when the diffusion begins; we have then

$$\frac{dA}{dt} = -\kappa A - \mu A$$

where μ is the diffusion constant for this gas through the porous plate used, and thus,

$$A = A_0 e^{-(\kappa+\mu)t}$$

and

$$I_0 = A_0 + E_0 = A_0\left(1 + \frac{a}{\lambda-\kappa}\right)$$

as before,

$$\frac{dE}{dt} = aA - \lambda E$$

which under the assumed initial conditions gives

$$E = \frac{aA_0}{\lambda-\kappa-\mu}\left\{e^{-(\kappa+\mu)t} - \frac{\kappa+\mu}{\lambda-\kappa}e^{-\lambda t}\right\}$$

and

$$I = A_0\left\{\left(1 + \frac{a}{\lambda-\kappa-\mu}\right)e^{-(\kappa+\mu)t} - \frac{a}{\lambda-\kappa}\,\frac{\kappa+\mu}{\lambda-\kappa-\mu}e^{-\lambda t}\right\} \quad (4)$$

and by properly choosing the value of μ this should fit the observations plotted in figs. 6 and 7. In order to get a first approximation to μ we may make use of the initial slope of the curve:

$$\left(\frac{dI}{dt}\right)_{t=0} = -A_0(\kappa+\mu)\left\{1 - \frac{a}{\lambda-\kappa-\mu}\left(1 - \frac{\lambda}{\lambda-\kappa}\right)\right\} \quad (5)$$

and since κ is so small in comparison with λ, we have approximately

$$\left(\frac{dI}{dt}\right)_{t=0} = -A_0(\kappa+\mu) \quad (5')$$

As has been pointed out, the value of A_0, that is the activity of the gas itself without the induced activity, is very imperfectly known. If we take the values indicated by the extensions of the curves in figs. 4 and 5 (30 to 40 per cent of the

total), the value of μ obtained from equation (5′) when substituted in (4) will not fit the observations. On the other hand, if it be assumed that between 50 and 60 per cent of the total activity is due to the gas, a reasonably good fit can be secured; and this value of A_0 is also indicated by a special experiment under better conditions in which a larger quantity of radium emanation was admitted rapidly; but even under the best conditions with the electrometer used, readings could not be obtained oftener than every $2\frac{1}{2}$ minutes, and thus the principal weight in the selection of a value for A_0 must be given to the diffusion curve. It is to be noted that the constant, a in (4), as determined from experiment, depends on the value chosen for A_0.

In the following table the second column is calculated from equation (4) with $A_0=56$, $\lambda=1{\cdot}36$, $\mu=0{\cdot}58$, which value gives a better fit than either 0·57 or 0·59. The third column gives the experimental values for the radium emanation as determined from the curve, fig. 7.

Time in hours.	Calc.	Curve.	Diff.
1	67·5	66·0	+1·5
2	40·2	41·2	−1·0
3	23·0	23·7	−0·7
4	12·9	12·0	−0·9

The differences are considerably less than the differences between the experiments for the earth-gas and the radium emanation; for the former, $\mu=0{\cdot}56$ appears to give the closest agreement. If we take 0·57 as the value from the two experiments and assume that Graham's law may be applied, we find that the density of the gas is 4·1 times that of carbon dioxide, which would give it a molecular weight of 180.

As our apparatus was conveniently arranged for use with radio-active gases, we attempted to determine the properties of the active gas recently obtained by Strutt* from metallic mercury. We were, however, unable to obtain any evidence of radio-activity from air which had been circulated through hot mercury for fourteen hours; and an increase of ten per cent over the "spontaneous" ionization in the cylinder could certainly have been detected. This would seem to indicate that the gas observed by Strutt was due to some radio-active impurity in the mercury which he used.

In connection with the evidence of the existence of minute quantities of radium in the ground in this vicinity, it is of

* Strutt, Phil. Mag., July, 1903.

interest that small quantities of pitchblende and other uranium minerals are found in Connecticut. The fact, however, that the gas, originally discovered by Professor Thomson in the Cambridge water, has also been found to be mainly, if not wholly, radium emanation,* and that the gas found by Elster and Geitel† in the soil in various places in Germany has the same general characteristics, make it not unlikely that radium may be very widely distributed in the earth, although not always in the surface layers.

Conclusions.

1. The radio-active gas found in the ground and in the surface water near New Haven is apparently identical with the emanation from radium. If any other radio-active constituent is present it can be only in very small proportion.
2. The density of the radium emanation, as determined by its rate of diffusion, is about four times that of carbon dioxide.
3. We were unable to obtain the radio-active gas from mercury, recently described by Strutt, and are therefore inclined to attribute his results to an impurity in the mercury used.

Sheffield Scientific School of Yale University, December, 1903.

* E. P. Adams, Phil. Mag., Nov., 1903.
† Elster and Geitel, Phys. Zeitsch., July 1, 1903.

ART. IX.—*Structure of the Upper Cretaceous Turtles of New Jersey: Adocus, Osteopygis, and Propleura;* by G. R. WIELAND. (With Plates I–IX.)

ONE of the most striking geologic features of New Jersey is the area of Upper Cretaceous Greensand or "Marl" which extends obliquely across the state from the Delaware Bay to Sandy Hook. Few Mesozoic formations yield a richer series of extinct vertebrates; and amongst these, the Testudinates, as here so well represented by marine, littoral, and doubtless land forms, are of great interest and importance from a biologic point of view.

These turtles mainly occur in the "Greensand" with the bones of birds, pterodactyls, dinosaurs, crocodiles, mosasaurs, gigantic fishes, and sharks, not many feet below a prominent and extensive bed of Gryphæas, preceded and followed by marls. There are implied abruptly changing conditions and a near shore; and there is a constant likelihood that there may here be found primitive marine or littoral turtles presenting characters allied to those of the old stocks from which the original marine turtles were derived, a fact which needless to say gives to the investigation of the specimens from the Greensand an exceptional value. For amongst the fundamental skeletal changes exhibited by extinct forms, none are more interesting than those connected with the evolution of flippers. Moreover the manner in which this took place in the turtles is rapidly nearing very complete demonstration. As yet, however, the structure of the Upper Cretaceous turtles of New Jersey has received but brief attention.

The carapace of *Adocus* as figured by Professor Marsh some years since, has made this the best known of these forms. But with this exception the descriptions and figures so far as given have been based on fragmentary material, and there has been little evidence presented as to the character of the limbs. Nevertheless the sand matrix, and the naturally disarticulated and uncrushed condition of the skeletal elements of these fossils (see Plate IX), afford the opportunity for rarely satisfactory study. In the following initial descriptions a more adequate knowledge of three of the genera is for the first time made available.

I. *Adocus punctatus* MARSH.—(With Plates I–IV.)

The genus *Adocus* was first assigned by Cope* to some fragmentary remains from the Upper Cretaceous or Greensand of New Jersey, these having been originally described by Leidy

* Proceedings of the Academy of Natural Sciences, Philadelphia, 1868.

as *Emys beatus*. The name *Adocus* (Gr. A, privative; and Δωχος, rafter) meaning literally without rafters, happily expresses the fact that the rib heads (with the exception of the first and second and tenth) are diminished to the merest line-like trace on the inner surface of the pleurals. The general characters of the genus, however, remained but vaguely known until the description of the carapace of the new species *Adocus punctatus* by Professor Marsh.* This was accompanied by an excellent woodcut, which is here reproduced. fig. 1.

1

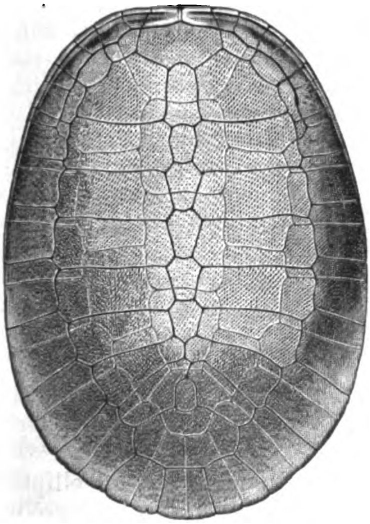

FIGURE 1.—*Adocus punctatus* Marsh (type). Carapace × ⅛.—The original figure by Professor Marsh.

Later the type was placed on exhibition in the Yale University Museum, although no attempt was made to bring the carapace and plastron into their normal position until recently. This having now been done, and this fine type having again been placed on exhibition as finely mounted in erect position by Mr. Hugh Gibb, an opportunity is afforded to supply the much needed figure of the plastron, and present further facts and figures showing the true form of this ornate and interesting Cretaceous turtle.

The remounting of the specimen proves that the outline of the carapace departs from the oval form shown in the original

* Notice of Some Extinct Testudinata. This Journal, vol. xl, 178 and 9, 1890. The type is from the long since abandoned pits of the old Cream Ridge Marl Co. near Hornerstown, Monmouth Co., New Jersey, and was received at the Yale Museum, Oct. 10, 1872.

figure, by a distinct narrowing in the anterior region, so that the greatest breadth is seen two-thirds of the entire length back. A very slight double curvature of the outer border also appears to be present, as shown in Plate 1. It is found, too, that there is less flattening of the carapace than is suggested in figure 1, the curvature rather closely approaching that of *Dermatemys mawii.** The unusual heavy furrow marking the boundary between the first vertebral and first pleural, also between these two elements and the nuchal and first four marginal horn shields, is shown in the orignal figure, as well as in the additional outline figure (Plate 1) drawn by the writer from the remounted specimen. In the latter figure the sutures are indicated by the serrate lines, and the boundaries of the horn shields by a triple line. With the prominent exception just noted, the other boundaries of the horn shields, though distinct, are indicated by a narrow and shallow groove only. The finely punctate sculpturing of the surface of the carapace is fairly well shown in Plate II, reproduced from a photograph. The punctations are of sub-triangular outline. They appear nearly as if made by the slightly blunted corner of a chisel blade, and approach regularity in their distribution.

The *plastron*, like the carapace, has a punctate surface. The preservation is also exquisite, and the complete trace of all the bony plates and horn shields may be accurately determined, as shown in my outline drawing, Plate III.

Synopsis of the Characters of Adocus.

Carapace.—Of rather elongate sub-elliptical outline, and composed of 48 bony plates with the grooves marking the borders of the 38 horn shields distinct, as follows:—

(*a*) Bony Plates: Marginals 11 pairs, large and heavy, the inner borders uniting solidly with other elements by suture; nuchal large, of sub-pentagonal outline and without nether or costiform processes; pygal as large as nuchal, and of sub-octagonal shape, its boundaries being the 9th neural, 8th pleurals, 11th pair of marginals, and the intervening pygal marginal; pygal marginal large and of sub-quadrilateral form; pleurals 8, the 2d–8th being without rib capitulæ, and the 7th and 8th meeting on the median line; neurals, 7 in all,—there being no true 7th and 8th, *the true 9th* following the interim formed by the median junction of the 7th and 8th pleurals.

(*b*) Horn Shields: A diminutive nuchal and 12 paired marginals, the first four pairs being intermediate in width between the same elements in *Osteopygis* and *Chelydra*, *and the others of large area rising high on the carapace;* 5 vertebralia; 4 pairs

* Table XXI, Gray's Catalogue of Shield Reptiles, Part I. London, 1855.

of costals, the first pair being large and overlapping the inner ends of marginals 1–4; the second and third of nearly the same area, width, and length as the second and third vertebrals. Unlike the 1st, the 2d–4th costals lie entirely on the pleuralia.

Plastron.—Of medium size, the length being two-thirds, and the least width of the bridge one-fourth that of the carapace. Anterior and posterior borders not emarginate, but slightly truncate or "abbreviated." Very heavy, and united to the carapace by sutures (cleidosternal union), with the strong axial and inguinal buttresses meeting respectively the 3d and the 8th marginalia. Composed of 9 heavy bony plates all strongly united by suture, with the narrow line-like furrows marking the borders of the twenty horny shields distinct.

(*a*) The *Bony Plates:* There are the usual eight paired plastrals with a rather large entoplastron of sub-hexagonal outline, and completely enclosed by the epi- and hyoplastra. The heavy axial buttress extends forward to the posterior portion only of the inner edge of the third marginal, and the large inguinal buttress (peduncle) backward to the anterior portion of the inner border of the 8th marginal. The inferior inner borders of these and the intervening 4th, 5th and 6th and 7th marginals pass well in to meet the plastral elements, and the bridge is firmly anchylosed.

(*b*) The *Horn Shields:* Intergular separated by a furrow or semi-divided into paired parts; gulars of sub-isosceles triangular outline; humerals meeting on a straight mesial line; but pectorals, ventrals, femorals and anals on an irregularly sinuous line crossing and recrossing the median sutural junction of the bony elements beneath; three paired inframarginals, axial, mesial and inguinal, with an indistinct small fourth pair well down in the humeral notch. All outlines indicated by fine lines or narrow grooves.

Adocus punctatus a Distinct Species.

In his original description Professor Marsh stated that the present type was most like *A. beatus* of Leidy, and the identity of these species has since been claimed by several. I find however, on comparing the figures of Leidy's type,* that specific differences are to be made out even from the fragmentary materials which constitute it. To make these clear, I show in figure 2 (*a* and *b*) the first left marginals of the forms in question. They are not of the same proportion, nor are the vertebral and marginal horn shields of so nearly the same outline as they would normally be in one and the same species.

* * * * * * *

* Leidy, Cretaceous Reptiles of the United States (Philadelphia, 1865), Plate XVIII, figures 1–3.

As pointed out by Marsh and later by Baur,* the nearest living relative of *Adocus* (the type genus of the Adocidae of

a 2 *b*

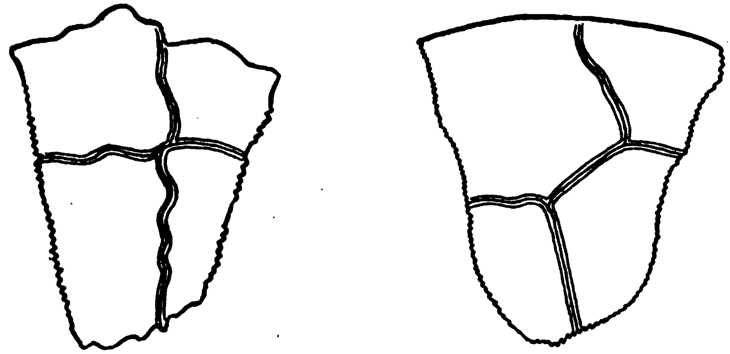

Figure 2.—*a. Adocus beatus* (type), left 1st marginal. $\times \frac{3}{8}$. After Leidy.
b. Adocus punctatus, Marsh (type), left 1st marginal. $\times \frac{3}{8}$.

Cope†) is *Dermatemys* of Yucatan, which with the genera *Staurotypus* and *Claudius* of Mexico and Central America, constitute the *Dermatemydidæ.*

The arrangement of the neuralia of *Dermatemys* is much the same as in *Adocus*, but there are only 46 plates in the carapace as figured by Boulanger (Brit. Mus. Cat.), the 7th pleural being large and representing the 7th and 8th of *Adocus.* Also, not only the first, but all the succeeding costals overlap the marginals. *Dermatemys* likewise differs markedly in the presence of a costiform process of the nuchal.

Four inframarginals are present, but there are no separate paired gulars as in *Adocus.* Unlike the latter, the plastron is notched posteriorly.

Measurements of Adocus punctatus Marsh (type).
Skeletal parts uncrushed.

(1) *The Carapace.*

Length on straight line	54. cm
Length over curvature	60.
Greatest width (across 5th neural)	37.
Distance over curvature across 5th neural	51.
Projection beyond front end of plastron	6.8
Projection beyond hinder end of plastron	12.2

* Proceedings of the Academy of Natural Sciences, Philadelphia, 1891, vol. xliii, p. 428–430.
† Proc. Amer. Phil. Soc., Philadelphia, 1870, xi, p. 515.

(2) *Bony Plates of the Carapace.*

	Length along outer edge of Carapace.	Middle length from lower edge of Carapace to interior borders.
Nuchal	6·5cm	7·2cm
1st Marginal	6·5	6·5
2d "	5·5	6·5
3d "	5·0	6·2
4th "	4·8	7·0
5th "	5·5	8·5
6th "	6·0	9·3
7th "	6·8	9·5
8th "	7·5	9·8
9th "	6·5	9·6
10th "	6·8	9·4
11th "	6·5	7·0
Median	6·8	6·3

	Length (antero-posterior).	Greatest width (lateral).
Nuchal	6·5	7·2
1st Neural	7·0	4·0
2d "	4·0	2·9
3d "	5·2	3·9
4th "	4·8	3·8
5th "	4·2	3·9
6th "	4·7	3·7
9th "	3·6	2·3
Pygal	7·2	11·2

	Length (laterally).	Width (across middle of plate).
1st Pleural	10·0	8·2
2d "	13·5	5·2
3d "	14·5	5·2
4th "	15·0	5·0
5th "	14·8	4·6
6th "	13·0	4·5
7th "	12·0	3·9
8th "	10·4	4·4

(3) *Carapacial Horn Shields.*

Length of 1st–11th Marginalia respectively, along outer edge of carapace, 6·2, 6·2, 5·1, 5·0, 5·3, 6·0, 6·3, 7·2, 7·5, 7·3, 7·0, 6·8 centimeters.

Length of 1st–4th Costalia respectively, 12·6, 11·8, 10·0, 7·2 centimeters.

Length of the Nuchal scute, 1·6.

Length of the 1st–5th vertebralia respectively, 10·2, 9·1, 10·4, 10·2, 8·3 centimeters.

(4) *Elements of the Plastron.*

	Greatest length on median line.	Greatest lateral width.
Epiplastron	2·5^{cm}	6·5^{cm}
Entoplastron	5·0	6·8
Hyoplastron	6·0	14·0
Hypoplastron	10·5	14·0
Xiphiplastron	11·	8·

(5) *Plastral Horn Shields.*

	Greatest length on median line.	Greatest lateral width.
Intergular	2·5	3·
Gular	(3·)	(4·)
Humeral	4·	8·5
Pectoral	4·	11·
Ventral	9·0	11·
Femoral	8·5	9·
Anal	7·5	7·

(6) *Thickness of various elements.*

Nuchal (at anterior median border)	1·1^{cm}
" (at posterior end)	·3 +
1st Neural (at anterior end)	·4
1st " (at posterior end)	1·0
5th " (anterior)	1·0
5th " (posterior)	1·0
7th " (average)	·5
1st Marginal (at the marginal–vertebral–costal horn shield intersection)	2·0
11th Marginal	1·3

II. *Osteopygis Gibbi* sp. nov.—(Plates V–VIII.)

The genus *Osteopygis* was proposed by Cope in 1868* for the reception of certain fossil turtles from the Upper Cretaceous Greensand Bed of New Jersey. In all some seven species have been referred to this genus. But they are quite without exception based on fragmentary material, for the greater part insufficiently illustrated and described. It is hence with the utmost difficulty, if at all, that one may adjudge the value of the several species without having at hand all of the types, which urgently require redescription and adequate illustration. This being the fact, the restoration for the first time of the complete shell of *Osteopygis* must be of immediate service and interest. The possibility of such a restoration is afforded by Yale Specimen No. 783.

* Proceedings of the Academy of Natural Sciences, Philadelphia, 1868, p. 147.

This finely preserved Carapace and Plastron is accompanied by a perfect right Femur and left Humerus, with the proximal end of the left Femur, the distal end of the right Humerus, a perfect left Ulna, both ends of the Tibia, the first and second left Metatarsalia, the 7th Cervical centrum, and some fragmentary cervicals.

All the parts just enumerated are believed to belong to one and the same individual. Lest the question should be raised, I state that the Carapace and Plastron are not composite. It was proven that every portion belonged to the same individual.

As now mounted and shown in Plates VI and VIII, almost the only restoration required was due to the loss of portions of the originally complete shell, at the time of collection. Fortunately, in no case is such restoration hypothetical. Invariably the outlines are delimited by unbroken opposing surfaces or articulations. The most serious loss was in the case of several of the neuralia, of which portions of the first and third, and all of the sixth–ninth were lost; but, fortunately, opposed sutural unions of these parts with the pleuralia indicate the outlines of all these bones. The pleuralia are practically complete, and neatly join. All the marginalia but the left 11th are present, complete, uncrushed, and suturally interlocked. As will be noted, the 9th neural and the anterior pygal are both distinctly assymmetric.

That the accompanying limb bones belonged to this particular carapace and plastron, is indicated by all the available evidence. When I began the study of this fossil as received with its various parts dissociated and some of them broken, I found accompanying it and bearing the same catalogue number, 783, a differently weathered left hyoplastral fragment, and a perfect left hypoplastron of the same size, and plainly of the same species as the plastron belonging to the carapace. In addition, there were most of the pleuralia, and several marginals of a much smaller turtle belonging to the genus *Lytoloma*, a much more distinctly marine form. None of these turtles can possibly be confused with the individual here described, and they constitute all the parts of the original shipment, as received from the West Jersey Marl Company of Barnsboro, Gloucester Co., New Jersey, May 17, 1870. These turtles came from the large marl pits, in the "Upper Greensand Beds," one and one-half miles east of the Barnsboro P. O., at which digging was abandoned about twenty years ago.

The present specimen, or 783 proper, clearly belongs to the genus *Osteopygis*, as commonly used. Though, of course, as Cope himself pointed out, this genus may ultimately be referred

to the prior one, *Euclastes.** For reasons given below, the species is considered a new one, and I take great pleasure in naming it in honor of Mr. Hugh Gibb, Preparateur at this Museum for more than twenty years past, and an excellent naturalist.

3

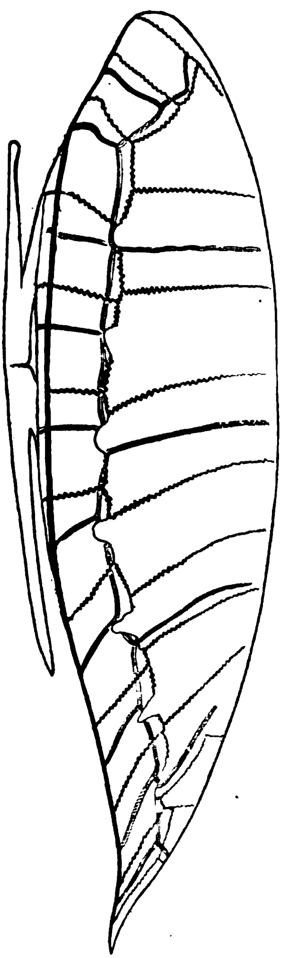

FIGURE 3.—*Osteopygis Gibbi* (type). Sketch of the lateral view of the carapace and plastron as mounted. × $\frac{1}{6}$.

Description.—The general outline of the Carapace is broadly subelliptical, the nuchal having only slight recurvature, and the pygal region forming a very obtuse angle.

As may be seen by referring to the side view, figure 3, the body is rather flat. The general outline is not unlike that of *Kachuga lineata*, the plastron being, however, much flatter and quite different. To get any comparison of plastral form, it is necessary to turn to the Dermatemydidæ or to *Chelydra*. The very large posterior marginals rise at a rather low angle. The surface of the bony plates is seldom pitted, except by accident, and is, especially over a large portion of the pleuralia, marked by closely set fine lines.

(A) *Carapace.*—Composed of 51 bony plates, with the boundaries of the 38 horn shields all clearly marked as deep and distinct furrows.

(1) *Bony Plates:* Marginals 11 pairs, all united to pleurals by sutures; the 2d deeply round pitted posteriorly for reception of outer anterior limb of the hyoplastron: the 7th–11th of broadly oblong shape, slightly concave on upper surface, the inferior faces being more strongly convex; external borders forming a continuous outer curvature from the nuchal to the ninth, but borders of 9–11 and the pygal marginal slightly convex; 4th–6th very slightly escalloped on inner upper border and exposing rib tips a little; 7th–10th with deep V-shaped notch in inner upper border distinctly exposing the tips of the ribs; rib pits flattened: mar-

* Extinct Batrachia, Reptilia, and Aves of North America, Trans. Amer. Phil. Soc., vol. xiv, 1869, page 140.

ginal-costal furrow crosses the posterior corner of M1, inner ends of M2 and 3, nearly or wholly coincides with inner borders of M4–6 and crosses inner ends of M7–11; nuchal, large, sub-pentagonal, anterior border nearly without nether or costiform process, straight as viewed vertically; pygal marginal of medium size, notched anteriorly: pleurals, 8 pairs, all uniting by sutures with the marginals, with the distal ends as broad as, or broader than, the proximal ends, and the flat ribs projecting peg-like into pits in the marginals (gomphosis): neurals 9, the first 8 about twice as long as broad,—No. 1 with rounded ends, Nos. 2–7 notched anteriorly, rounded posteriorly, No. 8, elliptical, No. 9 broader than long. Anterior pygal assymmetrical,—large, uniting with inner border of 10th and 11th marginals; posterior pygal of sub-trapezoidal outline, broadest in front, and with double curve in posterior border for reception of the anteriorly notched pygal marginal. (The anterior and posterior pygal are represented by a single pygal in *Adocus*.)

(2) *Horn Shields.*—The boundaries of all the horn shields are delimited by uniform deep border grooving on the bony plates: nuchal shield wide; 11 paired marginals, with a

4

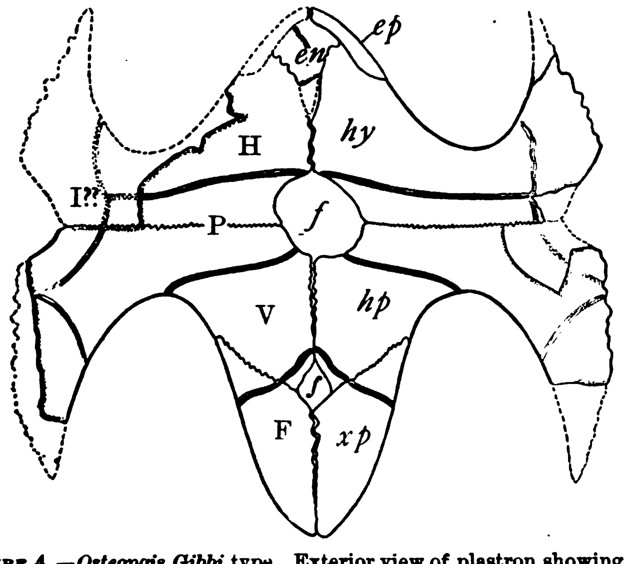

Figure 4.—*Osteopygis Gibbi* type. Exterior view of plastron showing horn-shield markings. × $\frac{1}{6}$.

(1) Bone plates.—*Ep*, epiplastron; *en*, entoplastron; *hy*, hyoplastron; *hp*, hypoplastron; *xp*, xiphiplastron; *f*, *f*, foramina.

(2) Horn shields.—H, humeral; P, pectoral; V, ventral; F, femoral; I??, region of indistinct inframarginals.

twelfth or supracaudal pair, none of which overlap the ends of the pleuralia; the 4th–10th rising just to, or a little above the bottom of the marginal notch above noted as exposing the rib-tips: costals 4 pairs, large: vertebralia 5, the 1st–3d and 5th of normal pattern, the 4th of ornate outline like the vertical section of a wide-mouthed and small-bottomed jug.

(B) *The Plastron.*—Of much reduced size, the length being about $\frac{3}{5}$, and the least width of the bridge less than $\frac{1}{6}$ that of the carapace. Composed of 9 bony plates, with the furrows marking the horn shields rather indistinct, but evidently as shown in text figure 4.

5

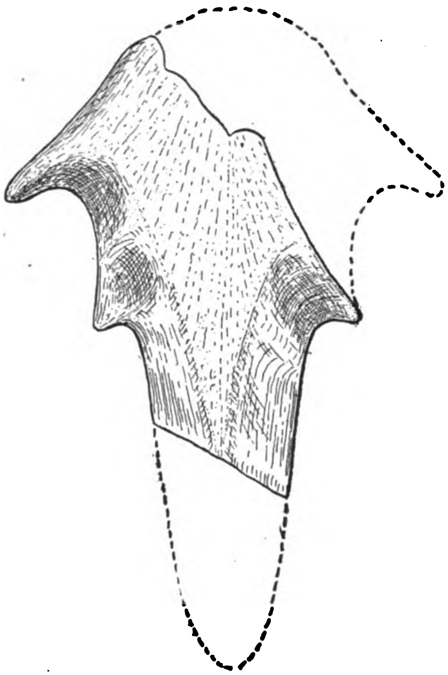

FIGURE 5.—*Osteopygis Gibbi* type. Entoplastron. Outer view, natural size.

(1) *Bony Plates.*—The general outline of the bony plates combines features of *Chelydra* and of the Dermatemydidæ. The narrow epiplastra meet at a rounded obtuse angle as in *Staurotypus*. The entoplastron, as shown in the accompanying text figure 5, exhibits a condition which is intermediate between that seen in a turtle like *Adocus*, and the reduced and rod-like condition in *Chelydra*. Union of the remaining elements on

the median line is by digitation—not by suture, with a large assymmetric and sub-oval median foramen at the hyo-hypoplastral, and a much smaller, at the hypo-xiphiplastral junction (*f*, *f*, figure 4). There are also small lateral foramina of crescentic outline between the 5th marginal and the hyo- and hypoplastron, as may be seen in Plate VIII.

The manner of the bridge connection with the carapace is of interest. Although truly dactylosternal, there are distinct suggestions of a former cleidosternal (closely interlocking suture) union as in *Adocus*. The axial and inguinal limbs or buttresses project into sockets in the posterior end of the 2d and the anterior end of the 8th marginals.

6

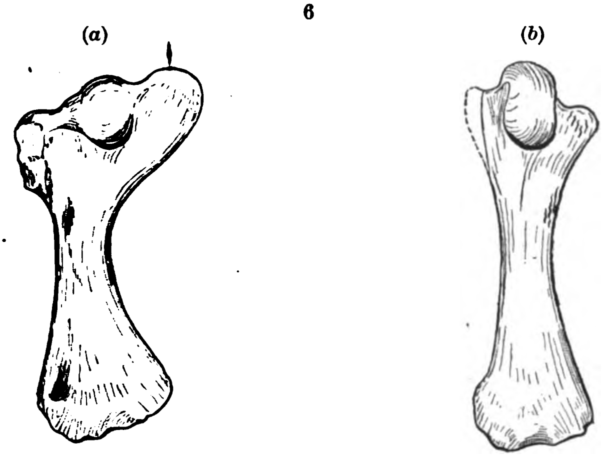

Figure 6.—***Osteopygis Gibbi*** **type. × ½.**
(a) Left humerus, dorsal view.
(b) Right femur, dorsal view, with fibular trochanter shown in dotted outline.

Cope speaks several times of a large rib cavity in the second marginal. But such cannot be present in any species of the genus *Osteopygis*. *The second, or first large rib, projects with strong backward curvature into a long claw-like depression in the third marginal.* The large pit in the second marginal appears to be a remnant of a former hollow beneath the axial buttress, and must serve mainly for muscular attachment, since only the lower edge is occupied by the end of the hyoplastral peduncle. The dactylations between the buttresses are short and robust. Those of the hyoplastron project against the lower inner border of the 3d and 4th marginals, which are pitted for their reception. Those of the hypoplastron project similarly against the 6th and 7th marginals. The hypoplastral

limbs or peduncles however pass gradually beneath the posterior edge of the seventh, and end as mentioned, in the anterior pit of the eighth marginals.

(2) *Horn Shields.*—The boundaries of the plastral horn shields are not all distinct, and these being the only portions whatsoever of either carapace or plastron that are not entirely so, it has been deemed best to indicate them, so far as determined, separately in text figure 4. As there shown, the inframarginal region is not clear. The anterior border of the pectorals, ventrals and femorals is however distinct, anals not being present, or else diminutive as in *Chelydra.* The gular boundaries do not show clearly, but these elements were probably small as in the existing *Staurotypus Salvinii*, with which there is in the general arrangement, number and size of parts a fairly striking comparison.

(C) *Limb and Other Bones.*—The *humerus*, as shown in text figure 6*a*, is in part intermediate between what I have termed the chelic (*Chelydra*) and the *parachelic* (*Testudo*) form.* The proximal end approaches the Chelydran form very distinctly. It is very large and the shaft slender. But the distal end is facetted, and in this respect approaches the grooved character seen in some forms of *Testudo.* The ectepicondylar foramen is a deep perforation. The only well-marked suggestion of departure in the direction of marine forms is afforded by the obtuse angle between the radial and ulnar crest, this being markedly greater than in *Chelydra.*

The *femur*, as might well be surmised in *Osteopygis* from the oval outline of the carapace, is as in *Chelydra* distinctly larger than the humerus (see figure 6 *a* and *b* in text). The

7

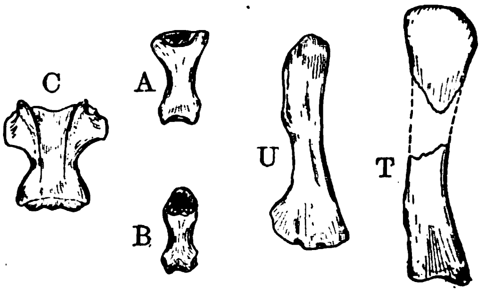

FIGURE 7.—*Osteopygis Gibbi* type. × ⅛.
C, superior view of seventh cervical centrum; A, superior view of first, and B, of the second left Metatarsalia; U, outer view of left Ulna; T, outer view of right Tibia.

* Some Observations on Certain Well Marked Stages in the Evolution of the Testudinate Humerus, this Journal, vol. ix, 1900, 413–424. See also, L'Evolution des Chéloniens Marin par L. Dollo, Bull. Acad. Roy. Belgique Cl. Sc. (Aug. 9, 1903).

most distinctive feature is the continuation of the articular surface well out on to the fibular crest. The distal end, as in the humerus, is facetted, not smooth. The characters of the ulna and of the tibia, and the several phalanges present, are in the main quite comparable feature by feature with these several elements in *Chelydra* (see text figure 7).

Of great interest is the form of the limbs. It is not to be said off hand that *Osteopygis* had flippers, as is implied by placing the genus in the Chelonidæ, as has been done in the American edition of Zittel's Handbuch. The limb bones above made known are not entirely conclusive on this point. The best study of the evidence at hand may be made from the following tabular statement:—

	Chelydra.	Osteopygis.	Eretmochelys.
Length of shell	(26·)	74·	(37·)
" humerus	6·	14·5	8·
" femur	6·4	15·	6·
" ulna	3·5	8·	4·
" 1st metatarsal	1·1	3·4	1·4
Ratio to length of shell.			
humerus	4·3	5·1	4·6
femur	4·0	4·9	6·1
ulna	7·4	9·2	9·2
1st metatarsal	23·6	21·8	26·4

The larger the ratio the smaller the part, whence *Osteopygis Gibbi* has a relatively shorter femur, humerus and ulna, with a longer metatarsal than *Chelydra*. But the humerus is relatively shorter than that of *Eretmochelys*, the femur relatively much longer. Comparison of the metatarsal in *Eretmochelys* cannot however be readily made since the hind flipper of the latter is so very greatly reduced. The conclusion I am led to is that the present species had by no means so well developed flippers as I have shown the primitive sea turtle *Toxochelys** to have had. But as the phalanges had undergone some elongation the toes must at least have been strongly webbed though doubtless they yet retained their claws. The smooth distal end of the humerus of the closely related *Propleura* is considerably more like that of the marine or natatorial types, and may indicate that these forms were undergoing some adaptation of the limbs for a pelagic or a littoral habitat. It would however seem that the marine Chelonians destined to survive were those which early acquired relatively powerful humeri, and it is probable that a form with a long femur like *Osteopygis*, even if the feet were fairly developed as flippers, was

* Notes on the Cretaceous Turtles *Toxochelys* and *Archelon* with a classification of the Marine Testudinata. This Journal, vol. xiv, 1902, p. 95.

not so good a swimmer as any of the existing marine turtles. In any case it is very evident that *Osteopygis* and the following closely related *Propleura* are among the most interesting of all known forms on the border line between littoral and marine Chelonians.

The 7th cervical is coelo-bicyrtean, the double convexity of the posterior end not being very marked. It is very broad in front, mainly because of heavy somewhat downwardly directed transverse processes, and had a heavy median keel running along its full length. The base of the neural arch is rather slender. Regarding the skull of *Osteopygis* we are as yet uncertain. It may prove to be like that of the prior genus *Euclastes*, as was thought possible by Cope or has since been assumed on ground not known to me. This remains to be carefully proven or disproven.

Systematic Position.—The type of the genus *Osteopygis* is the species *O. emarginatus*, and the present species appears to be more nearly related to it than to any of the several subsequently described forms. The type specimen of *Osteopygis Gibbi* differs from *O. emarginatus* in having a convex (not slightly concave*) outer surface of the 1st marginal, and in the conformation of the horn shields of the posterior marginals, several being distinctly smaller. Also the marginals are not notched. The lack of figures, and the fragmentary condition of the type, prevent further comparison.

In the case of *Osteopygis platylomus*, which has well marked pleuro-marginal fontanelles, the differences are clear, and it is not entirely certain that this species falls within the genus *Osteopygis*, which as hitherto constituted is quite certainly too far extended.

There is no living form to which *Osteopygis* can be at all so nearly compared as can be *Adocus* to *Dermatemys*. But if the carapace only be considered, there is a certain resemblance to such forms as *Kachuga* and *Hardella* (Burma and Pegu). On the other hand, there is marked similarity between the plastron of *Osteopygis* and that of *Staurotypus* of Central America. Moreover the carapace of this latter genus presents certain features that seemingly could have been derived from some ancestral *Osteopygid* form by fusion of parts, especially in the pygal region. It is therefore with the existing Central American genus *Staurotypus* that we may best compare *Osteopygis*, the differences however being of full family value. It is also very interesting how the dorsal characters of such a pleurodiran as *Plesiochelys solodurensis* (Upper Jura, Kimmeridgian) are strikingly like those of *Osteopygis*, while the plastron is almost identically like that of *Adocus*.

* Proc. of the Phil. Acad., May 12, 1868, p. 147.

—As to the exact systematic position of the family to which *Osteopygis* (and *Propleura*) belong I feel abundantly justified in for the present withholding final judgment, but think it would seem best for the time being to retain these genera in Cope's Propleuridæ, and separate *Lytoloma* in another family, the Lytolomidæ.

Measurements of Osteopygis Gibbi.
(Skeletal parts uncrushed.)

(A) *The Carapace.*

Length on straight line	$74{\cdot}3^{cm}$
" over curvature (greatest)	69·0
Greatest width	58· ±
Projection beyond front end of plastron	9·4
" " hinder " "	22·4

(1) *Bony Plates of the Carapace.*

	Exact length on outer edge of Carapace.	Length from lower edge of Carapace to union with pleurals.
Nuchal	$12{\cdot}7^{cm}$	....
1st Marginal	7·9	$6{\cdot}\ ^{cm}$
2d "	8·2	6·
3d "	7·5	6·1
4th "	7·6	6·
5th "	8·0	6·4
6th "	8·5	6·2
7th "	9·2	8·1
8th "	9·5	10·5
9th "	9·3	10·5
10th "	9·0	11·1
11th "	8·3	11·0
Median or Pygal Marginal	8·3	(7·1)

	Length.	Greatest width.
Nuchal	7·5	14·5
1st Neural	9·5	4·1
2d "	6·5	4·7
3d "	6·5	4·7
4th "	6·5	4·3
5th "	(5·)	3·7
6th "	(4·5)	3·3
7th "	(4·5)	3·0
8th "	(6.5)	(3·8)
9th "	(2.0)	(4·3)
Pygal (anterior)	6·	16·2
" (posterior)	6·	9·7
" marginal	7·1	8·3

	Length (laterally) over curvature along posterior sutural border.	Width across middle.
1st Pleural	21·0cm	10· cm
2d "	25·0	7·5
3d "	28·0	7·0
4th "	27·0	6·8
5th "	22·0	6·5
6th "	19·0	5·0
7th "	16·0	5·4
8th "	9·0	5·5

(2) *Carapacial Horn Shields.*

Extreme width of Nuchal .... 9·0cm

Length of 1st–11th Marginalia, respectively, along outer edge of carapace:—
5·4, 8·0, 8·1, 8·5, 7·3, 8·5, 9·5, 9·7, 9·7, 9·5, 8·0, 8·4cm

Greatest lateral length of 1st–4th Costalia, respectively,
21·0, 25·0, 22·0, 16·0cm

Greatest antero posterior length 1st–5th Vertebralia, respectively, 11·0, 14·0, 13·5, 14·0, 14·5cm

(B) *The Plastron.*

(Shields, Bony Plates.)

Length	43·0cm
Width, greatest	48·
Distance between axial and inguinal buttresses ..	38·5
Length of Epiplastron	9· ±
Width of Entoplastron	5·9
Least width across the hyo- and hypoplastral bridge	11·4
Greatest length of Xiphiplaston	18·5
" width of "	5·5

(C) *Other Skeletal Parts.*

(1) The *Humerus.*

Extreme length	15·1cm
Distance from outer border of radial to end of ulnar crest	7·5
Diameter of head (dorso-ventral)	3·0
Dorso-ventral thickness of middle of shaft	1·8
Greatest distal width	5·2
Distance of ectepicondylar foramen from anterior border.	·8

(2) *Femur.*

Extreme length	15·1
Antero-posterior diameter of head	2·3
" " " of middle of shaft	1·85
Greatest or antero-posterior distal width	4·5
(3) Greatest length of ulna	8·3
(4) " " of 1st metatarsal	3·4
(5) " " of 2d "	3·1
(6) " " of 7th cervical centrum	3·8

(D) *Thickness of Certain Bones of Carapace.*

Nuchal on median line				$1{\cdot}6^{cm}$
"	at ends			1·7
2d Marginal at anterior end				2·1
8th	"	"	border	2·6
8th	"	posterior	"	1·4
9th	"	"	"	1·4
Thickness 3d Marginal near inner border				0·6
7th Pleural at distal end				0·6

III. *Propleura Borealis* sp. nov.—(Plate IX.)

A new species belonging to a different genus from *Osteopygis*, but to the same family, the Propleuridae of Cope, is indicated by Yale Specimen No. 778, from the old Cream Ridge Marl Company's Pits, near Hornerstown, Monmouth Co., New Jersey. This fine Upper Cretaceous turtle was received at the Yale Museum in May, 1870. It consists in the nuchal; 1st and 2d neuralia; the 2d, 3rd, 5th, 6th and 7th right, and the 1st, 2d, 3rd, 5th and 6th left marginalia; the 1st and 2d, the 4th and 5th right pleuralia, with the 1st and 2d left pleuralia; the hyoplastron and hypoplastron of the right side, with both xiphiplastra; the left humerus, the pubis and ilium of the left side, and both ischia. None of these bones are crushed, and they are mostly little or not at all broken, and in a fine state of preservation, as may be seen by reference to Plate IX, where a photograph of all is given, the elements of the Carapace being placed in their approximately natural position, with the grooves marking the boundaries of the horn shields marked in ivory black water color. The portions of the plastron present are but very little broken, the view given being ventral, just as if the parts were brought out from their natural position beneath the carapace and to one side. Note that the antero-exterior limb of the plastron so often broken away in dactylosternal fossil plastra is entire. It projected into a pit at the posterior end of the second marginal, in the manner also seen in *Osteopygis*, and the interesting form of dactylate plastral union described above for that genus is also repeated in the present turtle. The humerus was broken in two, but the edges of the fracture unite solidly.

The pelvic elements unfortunately have their median symphysial borders broken away, but so much is present as to abundantly warrant their restoration, as shown laid flat and seen from the ventral side on Plate IX.

Description and Comparison with Osteopygis.

The form before us I shall, reviving Cope's genus, call *Propleura borealis.** The specific name may serve to lay

* Extinct Batrachia, Reptilia, and Aves of North America. Trans. Amer. Phil. Soc., vol. xiv, 1869, pages 138 et seq.

stress upon the fact that the nearest relatives of this turtle and its congeners are, so far as yet present in existing faunas, now mainly to be found in far southern lands. The species is next related to *Propleura* (Osteopygis) *erosa* of Cope, and to the type of the genus *Propleura* (Osteopygis) *sopita* as further noted below.

The arrangement of the plates and horn shields approaches that of *Osteopygis*, but there are many differences, the citation of which following the notes already made on this genus will answer quite fully the purposes of description. The differences follow:—

(*a*) The surface of the bones of the Carapace is not smooth to fine lined, as in *Osteopygis*, but coarsely round pitted to uneven depths, as if by numerous rain drop impressions of different sizes. Comparison of the surface of the various parts of the skeleton shows that while there are pittings present that may be ascribed to accidents of preservation, the characteristic pitting of the Carapace as shown in the plate is a true surface sculpturing. The pits are from 1 to 6^{mm} across, and from 1 to 3 or 4^{mm} deep, the average size being about 3^{mm} in diameter by 2^{mm} in depth.

(*b*) The proportion of the carapacial parts is quite different from that seen in *Osteopygis*. The nuchal has much more anterior concave curvature than in *O. Gibbi*, and though scarcely broader or longer, is nearly twice as thick. Contrariwise, the relatively much heavier second marginals are longer.

(*c*) The external border of the 6th and 7th marginals is notched at the boundary line of the horn shields, not unbroken as in *O. Gibbi*.

(*d*) The interior borders of the marginals present, following the anterior two-thirds of the second, which like all that of the first unites with the 1st pleural by suture, are smooth. Also the outer corners of the rib plates following the first end in oblique smooth edges, thus forming a series of well marked lateral or pleuro-marginal fontanelles, which lie opposite the marginal junctions beginning with the 2d and 3d, and likely extending to the 9th and 10th. These are of broad crescentic outline, and the one bounded by the 6th and 7th marginals and the 4th and 5th pleurals is 7^{cm} long and about half as wide. See Plate IX. There are no pleuro-marginal fontanelles in the distinctly smaller turtle *Osteopygis Gibbi*, and probably none in any specimen justly referable to the genus. Such fontanelles formed at the outer edges of the pleuralia constitute an anatomical feature that is quite different from the marginal notch over the 3d–9th rib tips as in *Osteopygis*.

(*e*) The rib pits are of rounded conical shape, and not flattened.

(*f*) The humerus of specimen 778 has much more rugose radial and ulnar crests than that of *Osteopygis*. Also corresponding well with the presence of pleuro-marginal fontanelles, the distal end is well rounded like that of *Chelydra*. The general form is chelic to chelicoid. The angle between the proximal crests is much more obtuse than in any of the Chelydridæ, and the ectepicondylar foramen is well enclosed. This latter is a retained primitive position.

The Pelvis.—The pelvis of the type just described is fortunately present as mentioned above, and can only be given separate description, since this portion of the skeleton of *Osteopygis* and allied forms has not hitherto been known. Although the median symphysial borders of both the pubes and ischia are broken away, the remainder of the pelvic outline is quite entire, and has warranted the restoration shown in Plate IX. There the parts are shown laid out flatwise and as seen from their lower, that is, from the acetabular side. The general structure and outline of parts is much like that seen in *Chelydra*, except that the distal articular surface of the pubis is much longer as in the marine turtle *Toxochelys*, which also has a somewhat Chelydra-like pelvis.

It is to be noted that the preceding facts and comparisons indicate a turtle close to *Propleura* (Osteopygis) *erosa* Cope, the type of which has not been figured. Cope says the species *O. erosus* has vertebral bones more than twice as long as wide, which *is not the case* in the 1st and 2d vertebrals, the only ones preserved, in the turtle before us. Completer knowledge of the two species may, however, show their identity. From *Propleura* (Osteopygis) *sopita* separation is based on the different proportions of the marginals, though in most other respects there is close agreement so far as may be adjudged from the fragmentary type material described and figured.* But generic separation of these specimens from *Osteopygis* must hold as based on the presence of well-marked lateral pleuro-marginal fontanelles, conical rib pits of the marginals, and humeri with smooth not sculptured distal ends.

Measurements of Propleura borealis.

Greatest width of Carapace		$65 \cdot 6^{cm}$
Length of Marginals measured along the outer edge:		
1st Marginal		10·0
2d	"	9·5
3d	"	7·5
4th	"	
5th	"	9·0
6th	"	10·4
7th	"	11·0

* Extinct Batrachia, Reptilia and Aves, Plate VII.

Length over curvature measured along posterior sutural borders.	
1st Pleural	21·0 cm
(2d ")	23·0
3d "	25·0
4th "	24·0
5th "	21·0
Width of Nuchal measured along anterior border	14·0
Greatest width of Nuchal	18·5
Anterior posterior length of Nuchal	9·0
Anterior-posterior length of first Neural	10·2
Greatest width 1st Neural	5·5
Greatest width 2d Neural	5·7

The Plastron.

Greatest lateral width of the hyoplastron	25·0
" " " hypoplastron	17·0
Length along median line of interdigition of Xiphiplastra	11·0

The Pelvis.

Distance from lower outer border of acetabular surface to base of the ento-ectopubic notch (or curve)	6·2
Distance from acetabulum to base of inner post ischial curve	5·5
Least distance from center of acetabulum to extremity of ilium (or surface of iliac support on carapace)	8·0

The Humerus.

(Normal in every respect.)

Extreme length	17·0
Distance from outer border of radial to end of ulnar crest	7·8
Diameter of head (dorso-ventral)	3·25
Dorso-ventral thickness of shaft	1·7
Greatest distal width	5·4
Distance of entepicondylar foramen from anterior border	1·1

Paleontological Laboratory,
Yale University Museum,
New Haven, Conn.

ART. X.—*Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. WORTMAN.

[Continued from vol. xvii, p. 33.]

Omomys pucillus Marsh.

Hemiacodon pucillus **Marsh, this Journal, 1872, p. 22, Separata.**

The type of this species, figure 124, consists of a fragment of a right mandibular ramus bearing the second molar, the structure of which agrees very closely with that of the corresponding tooth of *O. Carteri*, but the former is distinctly smaller. A second jaw fragment in which the second and third molars are preserved undoubtedly belongs to the same species. In my own collection, there are two jaw fragments in association with two superior molars, and in the Marsh collection there is one entire series of superior molars. These additional specimens, figures 125 and 126, furnish as complete a knowledge of the dentition as that described in the foregoing species. The dental formula of the lower jaw is the same as in *O. Carteri*, and with some few exceptions, which are of no more than specific importance, the details of structure are very similar. The chief distinctions separating *O.*

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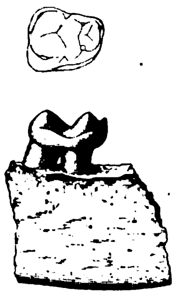

FIGURE 124.—Jaw fragment containing the lower molar of the right side of *Omomys pucillus* Marsh (type of *Hemiacodon pucillus* Marsh); side and crown views; a little more than four times natural size.

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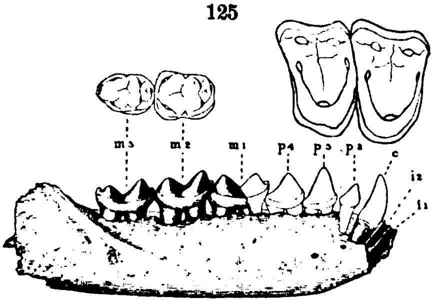

FIGURE 125.—Lower jaw and two superior molars of *Omomys pucillus* Marsh; side view of lower jaw, with side and crown views of teeth, and crown view of superior molars; the last are represented in outline five times natural size, while the lower jaw is a little less than three times natural size, and is drawn from three specimens.

pucillus from *O. Carteri* are the following: The species is considerably smaller; the last lower molar is slightly more reduced,

and there is a distinct ridge descending from the external cusp of the heel into the valley—a structure which is wanting in *O. Carteri;* the crown of the last upper molar is not so pointed internally; the postero-internal cusp is better developed upon the second than on the first molar; the intermediates are a little less distinct than in *O. Carteri.*

The species is thus far known from the lower and middle horizons of the Bridger.

Omomys Ameghini sp. nov.

A third still smaller species, which I refer provisionally to this genus, is represented by a fragment of a lower jaw of the left side, containing the second and third molars, figure 127. Besides being smaller in size than that of *O. pucillus*, the trigon is elevated above the heel to a much greater extent. This gives a somewhat insectivorous appearance to the teeth, but they are otherwise as in the species of *Omomys.*

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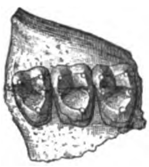

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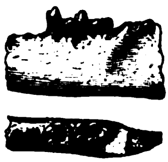

Figure 126.—Crown view of three superior molars of the right side of *Omomys pucillus* Marsh; two and one-half times natural size.
Figure 127.—Jaw fragment of the left side of *Omomys Ameghini* Wortman; side and crown views; two and one-half times natural size. (Type.)

The last molar is little reduced, and the anterior cusp of the trigon is distinct in both the second and third.

The locality from which the specimen was obtained is not mentioned on the label, unfortunately, so that its exact horizon is unknown. The specimen was found by Mr. J. W. Chew.

Omomys uintensis Osborn.

Microsyops uintensis Osborn, Bull. Amer. Mus. Nat. Hist., 1895, p. 77; ibid., June 28, 1902, p. 202.

This species of *Omomys* was founded upon a fragment of jaw from the Uinta, containing the third and fourth premolars and the first and second molars. The specimen is preserved in the American Museum collection, and has recently been figured by Osborn in his paper on the American Eocene Primates. At the time of its description, Osborn referred the specimen to the genus *Microsyops*, but in his last paper that reference is considered erroneous. After a careful examination of the type and a detailed comparison with *Omomys*, I am fully convinced that it is the Uinta representative of this

genus, and is therefore the only Primate thus far known from the Uppermost Eocene of North America.

Its relationship is at once seen in the elevated character of the crown of the third premolar, as well as in the general agreement in the structure of the teeth. It is, however, the largest species of the genus known, and exhibits a marked advance in the structure of the teeth, in the more widely separated and distinct condition of the internal cusp of the fourth premolar, as well as in the absence of the anterior cusp of the trigon on the second molar. The Bridger species are all smaller and more primitive.

Hemiacodon gracilis Marsh.

Hemiacodon gracilis Marsh, this Journal, September, 1872, Separata, August 13, 1872, p. 21; *Omomys gracilis* Osborn, American Eocene Primates, Bull. Amer. Mus. Nat. Hist., June, 1902, p. 173.

This is one of the most abundant species of monkey in the Bridger formation, and as far as the specimens show is confined to the upper levels of the horizon. The type upon

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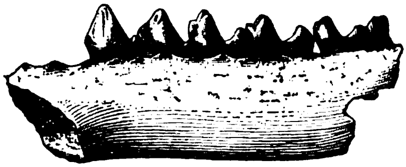

FIGURE 128.—Portion of right mandibular ramus of *Hemiacodon gracilis* Marsh; inside view; two and one-half times natural size. (Type of the genus and species.)

The elevation of the summit of the crown of the third premolar is greater in the type than in other specimens, on account of being partially out of the socket.

which Professor Marsh established the genus and species consists of a considerable part of a right mandibular ramus, figure 128, bearing the third and fourth premolars and the three molars in excellent preservation. The specimen also exhibits the alveoli for the second premolar, canine, and the two incisors, but is not sufficiently complete in front to admit of a determination of the number of incisors beyond all question. As compared with *Omomys Carteri*, the teeth of the lower jaw display in their structure a striking similarity to those of this species, and it is not at all surprising that Professor Marsh should have referred the two to the same genus. The chief differences consist in the enlargement of the first incisor and the reduced condition of the second incisor, canine, and second premolar, as well as in the better development of the internal cusp of the fourth premolar in *Hemiacodon gracilis*. The relations of the teeth in the front part of the jaw, I regard as

of more than specific importance, and these constitute in my estimation the main characters upon which the generic distinction rests.

In the molars the anterior cusp of the trigon is distinct in all, but least so in the last. There is likewise a very faint indication of a posterior median cusp in the heel of the first and second molars in the type, but in other specimens it is apparently absent. The posterior portion of the crown does not widen so rapidly as is the case in *Omomys Carteri*, the

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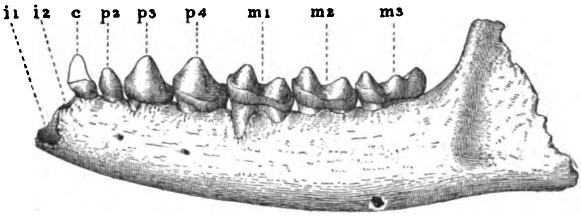

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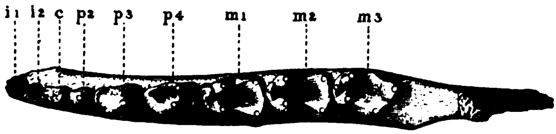

FIGURE 129.—Left lower jaw of *Hemiacodon gracilis* Marsh; external view; two and one-half times natural size; drawn from two specimens.
FIGURE 130.—Crown view of the same specimen.
In the drawing the alveolus of the first incisor does not appear as large as it actually is. The upper portion of the alveolus is broken away, so that only the bottom of the cavity is shown.

transverse diameter of the anterior and posterior moieties being more nearly equal. The fourth premolar is more advanced in structure than the corresponding tooth of *O. Carteri*. The third premolar in the type shows no trace of an internal cusp, but in some other specimens in the collection, of which forty or fifty individuals are represented, there is a distinct rudiment of this structure to be seen.

The second premolar and canine, figures 129 and 130, are preserved in several specimens, and their reduced size, as compared with the third premolar and the corresponding teeth of *O. Carteri*, is very evident. The incisors are not preserved in any specimen in the collection, but in several the front part of the jaw is sufficiently complete and well preserved to permit the alveoli to be made out with certainty. From these the number is shown to be two, of which the first is considerably larger than the second. The teeth were implanted in an uninterrupted

series and there is good evidence that the incisors were not very procumbent in position. The two halves of the lower jaw were not coössified, even in the most aged individuals.

In the upper jaw, figure 131, the teeth occur, in many examples, in association with those of the lower series. The structure of the molars is distinctive, not only by reason of the rather sharply quadrate outline of their crowns, but also because of their relatively great transverse extension. The first and second are subequal in size, and the third is considerably

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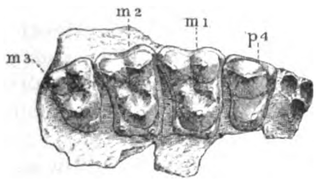

FIGURE 131.—Superior molars and fourth premolar of *Hemiacodon gracilis* Marsh; crown view; two and one-half times natural size.

The representation of the forward extension of the internal cingulum of the molars, as well as the size of the internal cingular cusp, is somewhat exaggerated.

reduced. The external cusps are moderately flattened upon their outer side, especially the posterior one, and they are bordered externally by a strong basal cingulum. The intermediates are unusually well developed, and there is a large internal pyramidal cusp. A small postero-internal cusp is developed from the cingulum, which continues forward around the inner side of the crown, and gives rise to a moderately strong subsidiary internal cusp. The extent to which this cusp, as well as the forward extension of the cingulum, is developed, however, appears to vary in the different specimens; in some the cusp is very distinct, while in others it is scarcely visible. The fourth premolar has single external and internal cusps. The third and fourth premolars are implanted by three roots, two external and one internal. The teeth anterior to these are unknown with certainty. The enamel is finely rugose in both the upper and the lower teeth.

In the fragment of a maxillary here figured, the anterior limits of the malar can be easily made out. It is thus shown that it does not reach forward to the lachrymal, but leaves the maxillary a considerable share in the anterior boundary of the orbit, as in the monkeys. The rather small, single, infraorbital foramen is situated above and opposite the posterior edge of the third premolar, about in the same relative position as that of the squirrel monkey. The maxillary gives further evidence of proportionally large orbits, and if the superior dental formula was the same as that for the lower jaw, the muzzle must have been considerably abbreviated. The whole aspect is, in

fact, not only characteristically Primate, but one considerably advanced.

In one specimen the head of a humerus is associated with a fragment of a lower jaw, which is apparently the proper size for *Hemiacodon gracilis*. The character of this bone is distinctly Primate. Among the living forms, it bears a closer resemblance to the humerus of *Propithecus* and *Avahis* than to any other with which I have compared it. This is particularly evident in the relatively great development of the lesser tuberosity and its inward and backward projection from the articular head. In this respect it also resembles the humerus of *Tarsius*, *Hapale*, and *Cebus*, although not so closely as it does that of the genera above mentioned. The large size of the lesser tuberosity is likewise a conspicuous feature of the humerus of *Limnotherium*, from which it may be concluded that it is a primitive character.

Professor Marsh has given the following measurements of the type:

Longitudinal extent of the nine lower teeth	20·5 mm
Extent of premolar and molar series	17·2
Extent of true molars	11·0
Antero-posterior diameter of last lower molar.....	4·0
Transverse diameter of last lower molar...........	2·4
Depth of jaw below last lower molar	6·3

The type specimen was found near Henry's Fork, by Mr. G. G. Lobdell, Jr. The other specimens of the collection are from the same horizon.

Hemiacodon pygmæus sp. nov.

A second species of this genus is indicated by a single superior molar, figure 132. Under ordinary circumstances, I should deprecate the proposal of a new specific name upon such an incomplete specimen, but in the present instance the relationship is so clearly indicated and the differences are so patent, that I do not hesitate to follow this otherwise reprehensible practice.

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FIGURE 132.—Superior molar of *Hemiacodon pygmæus* Wortman; crown view; four and one-third times natural size. (Type.)

The tooth in question displays its undoubted affinities with the molars of *Hemiacodon gracilis*, in its quadrate outline, its relatively great transverse extension, and the general arrangement of the cusps. The external cusps are somewhat more conical than those of *H. gracilis*, but the intermediate and internal cusps are practically the same as in that species. The great difference is seen in the size, *H. pygmæus* being but little more than one-half as large as *H.*

gracilis. It is possible that the tooth pertains to the small species described as *Omomys Ameghini*, but I do not think it likely.

The locality is not clearly indicated on the label, but the specimen was associated with other fragments from Dry Creek, which gives it an upper middle position in the Bridger horizon.

Euryacodon lepidus Marsh.

***Euryacodon lepidus* Marsh, this Journal, August and September, 1872, p. 33, Separata.**

Professor Marsh in describing this genus and species says: "A small mammal, doubtless an insectivore, is represented by a fragment of an upper jaw containing the last two molars in perfect condition. Our collections contain other characteristic fossils which appear to be specifically identical with this specimen. The teeth preserved agree nearly in the composition of their crowns with the molars described by Dr. Leidy under the name *Palæacodon verus*, but each has its inner margin produced into a small tubercle. In the penultimate upper molar, this tubercle is especially prominent. The outer margin, also, of these molars has but a single faint indentation between the external cusps. Both teeth are surrounded by a distinct basal ridge. The specimens preserved indicate an animal about as large as a weasel."

Besides the type, there are in the collection four other examples which I refer to this species. One of these is a fragment of an upper jaw bearing the second and third molars, just as in the type; and three lower jaw fragments, which, however, in no instance are associated with the upper molars. The reference of the latter to this species, therefore, contains an element of uncertainty.

The upper molars, figure 133, resemble those of *Omomys Carteri*. In the second molar of this latter species, however, figure 123, the anterior internal cingular cusp is not developed, while in *Euryacodon lepidus* it is strong. The last molar, moreover, in the latter species is a little less reduced and the crown is not so narrow and pointed, especially on its internal or lingual side. The external cusps are rather conical, and the intermediates are moderately well developed. The homologue of the main postero-internal cusp has a somewhat more external position, and this portion of the crown has a distinctly less rectangular outline than the corresponding tooth in *Omomys Carteri*.

In the lower jaw, figure 134 (if the specimens are correctly referred to this species), the molars only are known. The structure of their crowns is quite different from that of any species of *Omomys*. The anterior cusp of the trigon is well

developed in the first molar, and has nearly the same relations as in the corresponding tooth of *Omomys Carteri*. In the second molar, however, this cusp has a much more posterior position and is decidedly smaller, while in the third it is completely absent. The last molar is narrower and more reduced than in *Omomys*, and the heel lacks the distinct pointed cusps seen in all the species of that genus. The crowns of the upper molars, especially that of the second, are almost as wide in front as behind, being in marked contrast with the molar

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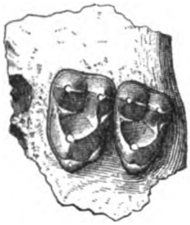

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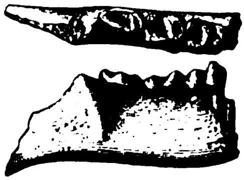

Figure 133.—Two superior molars of *Euryacodon lepidus* Marsh; crown view; a little less than four times natural size. (Type of genus and species.)

Figure 134.—Lower jaw fragment of *Euryacodon lepidus* Marsh; side and crown views; two and one-half times natural size.

crowns of the species of *Omomys*. Thus it will be seen that the lower molars of *Euryacodon* are more advanced than those of *Omomys*, and there can be apparently very little doubt that they represent distinct genera.

The complete dentition of the lower jaw is unknown, and I have provisionally referred the genus to the Omomyinæ. A comparison with the type of Cope's *Anaptomorphus æmulus*, from the lower horizon of the Bridger beds, shows many points of similarity. As is well known, the type of this latter species consists of a lower jaw in which the first and second molars are present, but the third is missing from the specimen. In *Anaptomorphus* the anterior cusp of the trigon has disappeared in both the first and second molars, which at once establishes the fact that it is at least a different species from *Euryacodon lepidus* and the most advanced form of Primate thus far known from the American Eocene. It is upon this account that I have chosen to regard *Euryacodon* and *Anaptomorphus* as distinct from each other, until the full dentition of the former and the upper teeth of the latter are more fully known. If *Euryacodon* is eventually found to possess only two premolars in the lower jaw, it will then probably be necessary to unite the two genera under the name *Euryacodon*, since the latter has distinct priority over *Anaptomorphus*.

[To be continued.]

ART. XI. — *The Structure of the Piedmont Plateau as shown in Maryland;* by EDWARD BENNETT MATHEWS. (With Plate X.)

THE structure of the more or less metamorphosed sedimentary and igneous rocks exposed in the Piedmont Plateau, lying between the Blue Ridge on the west and the Coastal Plain on the east along the Middle Atlantic coast from New York southward, is a geological problem of wide interest to American geologists and has occasioned more or less discussion among various investigators who have worked upon it.

Throughout the Piedmont region are exposed numerous highly-crystalline gneisses and schists intermingled with crystalline limestones, quartzites, and phyllites which have been intruded by large and small igneous masses of granite, gabbro, serpentine, and volcanic rocks; all of which have been metamorphosed in varying degree up to the point where they have lost all evidence of their original condition.

The deciphering of the various formations occurring within the Piedmont is still in progress and many areas are yet unstudied, but the areal distribution of the various formations throughout the region north of Virginia has been determined with sufficient accuracy to indicate the various types of rock present. The areas about Washington, Philadelphia, and a large portion of the intervening country within the limits of the State of Maryland, have been studied in detail until it seems that some clue has been gained regarding the broad structural features and geological relationship of this complicated region. In the present paper it is proposed to give a tentative interpretation of the broader structural features as shown in Maryland by the detailed mapping of the author and his assistants during the last seven years. The basis of work* includes a reconnaissance of the entire Maryland Piedmont and the detailed mapping of approximately 1250 square miles lying north and east of Baltimore.

General Characteristics of the Piedmont.

The crystalline rocks of the Piedmont Plateau are well exposed in the area about New York, where they have been

* While the work in Maryland has been in progress, the author has had many office and field conferences with Dr. Bascom, who has generously allowed him to examine and to use her detailed manuscript maps of the Philadelphia area. The work in Maryland has been conducted independently at the same time and both investigators have been led to similar results for their special regions. The application of their common interpretation to the whole area of the Eastern Piedmont is here first issued by the author, who wishes to acknowledge the assistance received from his knowledge of Dr. Bascom's results which have most generously been placed at his disposal.

studied by Dr. F. J. H. Merrill* and his colleagues. Southward from the New York area the older crystalline rocks of the Piedmont are covered by the formations of the Jura-trias and do not appear again until in the vicinity of Trenton, whence they pass southwestward across Pennsylvania into Maryland, offering numerous good exposures along the banks of the Delaware, Schuylkill, and Brandywine, where they have been investigated by members of the Pennsylvania Survey and more recently in great detail by Dr. Bascom. Within the limits of Maryland the Piedmont crystallines are trenched by the Susquehanna, Gunpowder, Patapsco, Patuxent, and Potomac rivers and their tributaries. Beyond the Potomac, the same formations are continued southward through Virginia, North and South Carolina, Georgia and Alabama, where they have been examined by members of the different State surveys and by Mr. Arthur Keith of the U. S. Geological Survey.

In each of the areas studied, about New York, Philadelphia, Baltimore, and Washington, similar series of rocks have been found but the interpretation of their relationship has varied somewhat, and until recently no attempt has been made to determine the structure of the territory. The following table represents the lithologic types recognized in the different regions by the various authors.

From the following table it is easily seen that four distinct types of rocks have been recognized in each of the areas, though not always represented on the maps accompanying the verbal description. These are (1) a banded gneiss, (2) a thin-bedded or arkosic quartzite, (3) a marble, and (4) a series of mica schists.

Banded Gneiss.—In each of the areas is a highly crystalline gneiss composed of quartz, feldspar and mica with accessory minerals so distributed as to produce a well-marked gray banded gneiss, the individual bands of which vary from a fraction of an inch upward, the average thickness, however, being quite small. Some of these beds are highly quartzose resembling a micaceous quartzite, others are rich in biotite or hornblende producing dark to black bands indistinguishable in a hand specimen from mica and hornblende schists and gneisses derived from igneous rocks by metamorphism. Through these banded gneisses are intruded pegmatite and aplitic dikes more or less parallel to the regular banding of the gneiss. In all of the areas these beds are found highly inclined in their banding, which represents original variation in composition of the sediments or the igneous rocks from which they were formed. Some authors have regarded these as sedimentary, some as

* N. Y. Folio, Geologic Atlas of the United States, Folio No. 83, Washington, 1902.

... Coastal Plain Deposits of Jurassic-Recent age on the east; separated from the underlying rocks by a marked unconformity.

	New York area.	Philadelphia area.	Maryland area.		Washington area.
	Merrill.	Dr. Bascom.*	Williams.	Mathews.	Keith.
Silurian	Hudson schist, mica schist with garnet, staurolite, fibrolite, cyanite	Hudson mica schist and Wissahickon mica gneiss	Peach bottom slates; Phyllite mica-schist muscovite-gneiss (in part)	Peach bottom slates; Cardiff quartz conglomerate. Wissahickon mica schist including phyllite member at top	
Cambro-Ordovician	Stockbridge limestone.	Chester Valley limestone	Dolomite or marble	Cockeyville marble	
Cambrian	Poughquag quartzite, thin-bedded white to brownish carrying tourmaline and muscovite	Valley Forge and Edge Hill quartzite	Setters quartzite	Setters quartzite	
Pre-Cambrian	Fordham gneiss, gray banded, potash, feldspar, quartz, mica, hornblende	Arrowmink arkosic gneiss	Biotite gneiss muscovite gneiss (in part)	Baltimore gneiss	Carolina gneiss (in part)

* Dr. Bascom has furnished the following correlation of formations as recognized by different investigators in the Philadelphia area:

Rogers.	*Hall.*	*Bascom.*
Talcose and micaceous slate (middle member of Primal series)	Quartzose slate and mica schists (Rand's hydro-mica schists)	Hudson mica schists and
First and second gneissic belts	Chestnut Hill garnetiferous schists; Manayunk mica-schists; Philadelphia schists and gneisses (in part)	Wissahickon mica-gneiss (Hudson age)
Auroral limestone	Limestone, No. II	Chester Valley limestone (Cambro-Ordovician age)
Primal sandstone	Potsdam, No. I	Valley Forge and Edge Hill quartzite (Lower Cambrian)
Third gneiss belt	Eozoic or Azoic or Laurentian gneiss (in part)	Arrowmink arkosic gneiss (Pre-Cambrian)

This is exclusive of igneous material. The Overbrook porphyritic granite-gneiss is included in Hall's Philadelphia gneisses and the great gabbro intrusive forms a large part of the Laurentian gneiss (so-called) which also includes some of the Wissahickon mica-gneiss (Frazer).

igneous, some as sedimentary masses intruded by igneous rock to form so-called injection gneisses. All have agreed that these banded gneisses are probably pre-Cambrian in age whatever their origin. Usually in eastern Maryland they are separated from other metamorphosed sedimentary rocks by igneous masses, but in the vicinity of Baltimore and in the Philadelphia area, as shown by Dr. Bascom, these banded gneisses immediately underlie the quartzite.

The Quartzite.—The quartzite is a fine-grained, somewhat saccharoidal, thin-bedded quartzite of white-brown color. The beds are usually separated by thin films of muscovite in small sparkling flakes. On the surface of these mica-covered cleavage or bedding planes frequently occur black tourmaline crystals which occasionally show evidence of movement along these planes. Individual specimens of the quartzite when massive may appear like the quartzose layers of the banded gneiss, but usually the rock is easily distinguished in the field. It generally is found dipping at a rather steep angle and because of its resistance to weathering is often a topographic feature of the region. This is a relatively thin formation which varies much in thickness from one to several hundred feet. Where this quartzite has been studied in anticlines and synclines, both normal and overturned, it appears to be younger than the banded gneiss and older than the neighboring marble.

The Marble.—The marble is a coarse-grained to medium-grained impure dolomite in which the impurities have been entirely recrystallized into silicates such as diopside, tremolite, phlogopite, etc. It is almost always a dolomite in chemical composition but may vary occasionally to a pure calcite rock. The bedding in these rocks is not easily recognized, but it is probable that the lines of impurity now represented by silicates indicate original differences in the sedimentary deposits. The amount of such impurities causes the rock to vary widely from a pure carbonate to one so rich in silicates that it may easily be mistaken for a gneiss until tested for hardness or with acid. These beds in the marble show considerable variation in the steepness of their dip, ranging from 10° up to 70° and occasionally they are found in overturned anticlines and synclines. The thickness of the formation is very variable and practically indeterminate on account of the paucity of exposures. Its presence is usually indicated by valleys along the sides of the quartzite ridges and its thickness apparently varies from nothing up to more than 2000 feet. No fossils have been found in the highly crystalline marbles and it is improbable that if originally present they could have withstood the changes which this rock has undergone.* The formation, however, has been traced

* A few deformed chert nodules have been found and they may yield microscopic forms on closer examination.

at several points into less metamorphosed rocks of similar composition where rocks of Upper Cambrian and Lower Silurian age have been found. Thus, it has been correlated with the Stockbridge limestone of western New England, the Chester Valley limestone of Pennsylvania, and tentatively with the Shenandoah limestones of Maryland and Virginia though no stratigraphic continuity has been established with the latter.

The Mica-Schists.—The mica-schist is composed of a series of highly micaceous, very schistose, and often crinkled aggregates of quartz, more or less decomposed biotite and garnet, with accessory orthoclase, cyanite, staurolite, fibrolite, etc. With the increase in feldspar the rock becomes a gneiss but is not as distinctly banded as the banded gneiss already referred to. The formation is chiefly characterized by the high content of mica, garnets, and occasional metamorphic minerals, and the small amounts of feldspar. The soils developed from the decomposition of the mica-schists are usually marked by an abundance of mica and rounded garnets. Beds of this type are only indistinctly marked and are separated with difficulty from the cleavage lines which may nearly parallel them. The entire formation has been much folded and it is not possible to make accurate determinations of the thickness. At first sight it would appear to be miles in thickness but in reality is probably not far from 2000 feet. The age of the rocks included under this term is not determinable by fossils carried by them, but, as in the case of the marbles, these schists have been correlated with less metamorphosed representatives which carry a fauna of Hudson River age.

The variation in the character of the marble through increased impurities causes the contact between the overlying mica-schist and the limestone to be one of gradation at times, and occasionally there seems to be a layer of more argillaceous mica-schists lying between the underlying quartzite and the well-defined marble.

Igneous Rocks.—Throughout the Piedmont area under discussion have been recognized numerous igneous rocks, now more or less metamorphosed, which are apparently intruded into all of the rocks as old as the mica-schists. Among the types found are granites and granite-gneisses, diorites and meta-diorites, gabbros and meta-gabbros, peridotites, pyroxenites and serpentines, meta-rhyolites, and meta-basalts. The contacts between these various masses are seldom exposed and the relative age of the various intrusions cannot be determined with entire satisfaction. So far as is known, the facts accord with the commonly accepted view that they represent in a large way a single period of igneous activity which no doubt extended over a considerable period of time. Just when these sheets

and larger intrusive bodies were thrust into their present position is not known, but the views most generally held at the present time indicate that the intrusion took place in post-Silurian time prior to the earth movements which produced the Appalachian Mountains. Earlier investigators and some at the present time express the opinion that this igneous activity was contemporaneous with the formation of the earliest rocks.

Metamorphism.—The older rocks of the Piedmont, as recognized by all investigators, have suffered more or less recrystallization and textural modification since their formation. This metamorphism has not been uniformly distributed over the entire region but, as emphasized by Williams, is much accentuated in the eastern portion of the Maryland area, where the rocks are thoroughly recrystallized and often lack in great measure their original texture. The original muds and sands of the sedimentaries have been changed to micaceous schists, gneisses, and quartzites and the various igneous rocks have been greatly modified in texture and occasionally in mineralogical composition. The textural change which is most evident is a marked development of schistosity which is to be noticed in all of the rock types already described. The change from massive to schistose rocks has not been uniform over the entire district or even over the more metamorphosed eastern section, but seems to be locally accentuated along lines which probably indicate zones of greater dynamic action.

The schistosity developed in the rocks of the Piedmont partakes of the general northeast-southwest trend of the province and varies in dip sometimes to the eastward and sometimes to the westward. It is present in both the sedimentary and igneous rocks. In the latter, it is sometimes so strongly developed that the resulting rocks in small areas present the appearance of metamorphosed sediments, although one may find all gradations between the unaltered massive types and the equivalent fissile schists. In the sedimentary rocks the schistosity is developed to a degree which greatly obscures the original bedding and oftentimes renders the determination of bedding planes impossible.

The development of schistosity is accompanied by a recrystallization of the affected rocks, which may simply result in a new development of the mineral species found in the original rock or in a molecular rearrangement producing many new minerals. Thus the gneisses are composed of recrystallized quartz, feldspar, and mica material, while the feldspars of some of the granites, the meta-rhyolites, gabbros, and diorites have been changed to epidote and the pyroxenes to fibrous or compact hornblende. The new minerals usually lie with their longer axes parallel to the planes of schistosity. In the case

of the phyllites and mica-schists the original material has been changed to muscovite, chlorite, and quartz with accessory minerals such as garnet, staurolite, cyanite, etc.

Structure of the Maryland Piedmont.

The four types of metamorphosed rocks with their accompanying igneous types unite in the Piedmont area of Maryland to form a complex geological mass in which the structure of the region is very greatly obscured by the metamorphism, secondary schistosity, and recrystallization. The problem is still further complicated by the presence of several series of minor folds which obscure the larger structural features of the region. The centering of attention on these minor structural features rather than on the broader elements of structure have led previous students of the area to divergent interpretation, or despair at ever reaching a true solution.

Previous Interpretations.—The Piedmont Plateau of Maryland has been studied by many investigators and the interpretations which they have given to the area may be classified, as suggested by Williams, into three categories, involving differences in age in the sedimentaries of the eastern and western portions of the area or differences in the structural elements which have brought the rocks to their present position. The three hypotheses as outlined by Professor Williams* are:

"1. That the rocks of both the eastern and western areas are of the same age, and that they have been bent into a broad syncline whose flanks are so sharply folded, faulted and thrust as to simulate the fan-structure observed in high mountain chains; and that the eastern flank of this synclinal or fan was much more highly metamorphosed than the western both by more intense dynamic action and by intrusion of a great amount of eruptive material.

2. That the more highly crystalline eastern area is greatly older than the western schists, and served as a rigid buttress against which these were thrust and folded.

3. That the eastern area is composed of rocks far more ancient than the western, which extend out under these, forming the floor upon which they were deposited; and that although already much folded and metamorphosed, this crystalline floor underwent at least one more folding after the schists had been laid down, carrying these with it and involving them in a considerable but not an extreme amount of disturbance and metamorphism."

The first of these hypotheses was that held by Tyson, who was State Agricultural Chemist from 1853 to 1862, and who published the first complete geological map of Maryland in

* Bull. Geol. Soc. Amer., vol. ii, p. 315.

1859. According to this view the structure is a more or less deformed synclinorium. This hypothesis, together with the second, is regarded as untenable by Williams on the grounds enumerated in his paper on the subject, where he proposed the third hypothesis as the most reasonable explanation of the facts and the one to be accepted as most probable unless subsequent explorations should render its modification necessary.

At the time Williams proposed this hypothesis no part of the Maryland Piedmont had been mapped by the U. S. Geological Survey, and the maps at his disposal consisted of inaccurate road maps of the various counties. At this time also the detailed mapping of the Piedmont, which was later prosecuted by him with success, had not been pursued beyond the immediate vicinity of Baltimore, where the structure is somewhat exceptional. The conclusions drawn were based upon several driving trips across the Piedmont Plateau in different directions, and the generalizations reached, while brilliant for the amount of information in his possession, are such as to demand modifications as the detailed mapping of the Piedmont on the scale of a mile to the inch by the Maryland Geological Survey progresses.

Results of Later Work.—Shortly after the publication by Williams of the paper referred to, the writer commenced a mapping of local areas under the former's direction and has continued field investigations as opportunity presented during the twelve years, until fully 1200 square miles of the Piedmont have been mapped on the scale of 1 : 62,500 and the entire Piedmont has been visited in economic work demanding greater or less local detail. The work of deciphering the structure of the Piedmont of Maryland is by no means ended, but it is proposed to give in the following pages what are believed to be the general lines of structural uplift and depression across the area. Many local questions still remain unsolved and much detailed mapping is still necessary in the western portion of the Plateau, but the views here expressed have been found to present the most reasonable interpretation of the area studied. Moreover, while they have been developed independently they are found on comparison to be more or less in accord with the structural interpretations resulting from the most recent work in corresponding areas to the north and south.

The methods employed in the investigation of the Piedmont geology embrace a consideration of all of the data available under the conditions encountered. The region considered lies south of the zone covered by the continental ice, and as a consequence few exposures of fresh rock are encountered except in the recent stream cuttings or in artificial openings. At the same time, bowlders and disintegration products found on the

surface are usually indicative of the character of the underlying rock. Throughout most of the area, especially in the little-dissected remnants of the old peneplane, the disintegration has extended from one to twenty or thirty feet, according to the character of the rock, and one may find entirely disintegrated masses of clay or sand retaining the original textures of the parent rock. Even much of the material which at first is so hard as to require blasting, breaks down when exposed for some time to the influence of the atmosphere. Disintegration of this type leaves few exposures and renders microscopic studies of many apparently fresh specimens unsatisfactory, but in turn facilitates the areal mapping since the soils and minor features of the disintegrated products are often characteristic of the underlying rock. The plant cover is also occasionally distinctive since certain forms of plant life are found limited to the areas underlain by certain rock types or there possess certain peculiarities of development.

The lack of fresh exposures and the detailed complexity produced by the schistosity and minor plications make it exceedingly difficult to determine the true bedding plane, and this is not possible in many instances. It becomes necessary therefore, to lay relatively less stress on the structural features found in single small exposures and to assign greater importance to the areal distribution and the general structural features determined by it.

Fossils have been found in only one or two areas, where they are much distorted or damaged and there is little hope that other deposits of better preserved forms will be found; for only the most hardy forms could withstand the metamorphic changes which the rocks have undergone.

The types of structure encountered in the region are joints, normal faults (usually of small throw), folds and probable unconformities. The *jointing* is usually in three fairly well-defined series of joints which cause the rock to break into irregular rhomboids. When well exposed in the banded-gneisses of the Baltimore and other areas, they show little or no movements along their planes although now and then a displacement of a few inches may be found along fault planes which are more or less parallel to the planes of jointing. The *faulting*, if present, is usually obscured by the homogeneous character of the rocks and the lack of well-defined bedding in many of the sedimentary masses where the faulting is exposed. It is accordingly impossible to trace the faults beyond the exposures in which they are found. So far as examined the throw of these faults is slight, ranging from a few inches up to a foot or two, and the general faulting structure partakes of that characteristic for the Jura-triassic beds which overlie the Piedmont on

its western border. Large overthrust faults may perhaps occur in the region, obscured by the similarity of deposits and the vegetation, but no evidence up to the present time has been found warranting the assumption of such overthrust faults unless, perhaps, in the region a few miles west of the Northern Central Railway, at a point twenty-five miles north of Baltimore. If such a fault occurs here, the plane of the overthrust must be very flat and the extent of the thrust small, since the areal distribution of the phyllites to the north and the gneisses to the south show no appreciable break in their boundaries. It seems more probable to the author that the recurrence of the marble in a series of parallel bands is due to folding or minor faulting than to an overthrust.

The *folding* in the rocks of the area is of three types: minute crinkling, small unsymmetrical wavy folds, and broad Appa-

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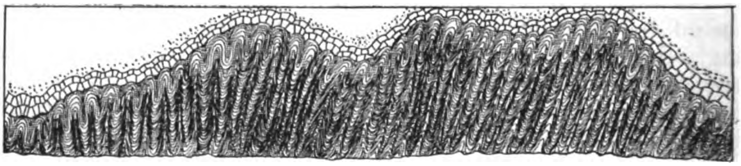

lachian ones in which the adjustment appears to have taken place along the bedding. The accompanying figure indicates the differences as sketched from exposures in the field. The intricacy of the minor folds has been the feature usually noticed by earlier investigators, who have many times overlooked the gentler open folding of the larger folds. In the succeeding discussion the emphasis will be laid upon these larger folds and less attention will be drawn to the minor ones, since the broader rather than the detailed local structure of the Maryland Piedmont is the problem under discussion.

The dip observations made on small exposures often relate to the minor folding and are usually quite steep, ranging from 40° to 80° with an average of 55° in the exposures. These dips are usually considerably at variance within short distances, although there seems to be a tendency for the exposures to be formed on those portions of the minor folds where their dip is in the same direction as that of the major fold, the return dips being usually concealed. The earlier structural interpretations have been based for the most part, in Maryland at least, on the dips of these secondary folds, and it has accordingly been customary to regard the region as one of steep monoclinal or closely compressed overturned folding. The dips of

the major folds, as determined by tracing individual beds with their sinuosities across the larger exposures, are much flatter than those of the minor folds, usually ranging in value from 5° to 40° with an average of between 25° and 30°. In many instances it is not possible to determine this major dip, but the areal distribution of the rocks is generally found to be in harmony with such observations as can be made.

Overturned folds are occasionally encountered, the best example so far studied occurring just west of the Baltimore-Harford county boundary line, about five to ten miles south of the phyllite boundary. The structure here is well marked by the occurrence of a quartzite, an intermittent marble, and the mica-gneisses surrounding a core of banded mica- and hornblende-gneisses. Contrary to the usual interpretation, this large fold is overturned to the southeast, causing all the dips to slope to the west.

Unconformities apparently occur in the crystalline rocks of the Piedmont, especially at the base of the quartzite and the top of the marble, but it is very difficult to determine whether or not the latter is due to a change in the character of the original limestone which, when highly argillaceous, is metamorphosed into a calcareous gneiss or mica-schist which is practically indistinguishable by field observation from the adjoining rocks. The points where this unconformity has been supposed lie near the limits of the area in which marble occurs, and it seems highly probable that the conditions of the formation of a limestone became less favorable around the limits of the area, and that through gradation the limestones pass off into rocks which, when metamorphosed, are indistinguishable from the overlying mica-schists.

Geological Sequence.—The field work conducted by the author and his associates on the Maryland Geological Survey indicates that in the Maryland Piedmont we have the following series of metamorphosed rocks which were apparently of sedimentary origin.

Peach Bottom slates Cardiff quartzite	Silurian (?)
Wissahickon phyllite, mica-schist and mica-gneiss	Ordovician
Cockeysville marble	Cambro-Ordovician
Chickies quartzite or Setters quartz schist	Lower Cambrian
Baltimore gneiss	Pre-Cambrian

The determination of the age of these formations by fossils is impossible at the present time in Maryland, and the age assigned the various beds is therefore regarded as somewhat

unproven, but, as already outlined in the first part of this paper, the sequence here is comparable to that of the similarly situated areas farther north where they have been correlated with less metamorphosed beds bearing fossils. The lithological features and structural characteristics are the same in the different regions and it is probable that this correlation is the true one and that it must, perhaps forever, remain unproven for certain portions of the Maryland region where the beds are separated from other sedimentaries by igneous rocks. As the work now in progress under the joint auspices of the Maryland and U. S. Geological Survey goes forward, it may be possible to correlate on structural grounds the limestones with fossil-bearing beds near Frederick, and it is possible that well-preserved fossils may be found in the less metamorphosed sedimentaries of the Frederick valley to the west of Parr's Ridge, as Mr. Keith has already detected fragments in this region.

Igneous Rocks.—Through these sedimentary rocks have been intruded large masses of igneous material which have consolidated into granites, gabbros, and other igneous types. Formerly it was regarded that the masses were intruded in pre-Cambrian time and that they were contemporaneous with the metamorphism of the crystallines. This cannot be wholly the case if the foregoing interpretation of the age of the sediments is correct, since these igneous rocks are intruded into the rocks here considered of Silurian age.

The areal distribution of the formations enumerated above is given in the accompanying map (Plate X) which has been compiled from the published maps of the New York and Pennsylvania state surveys; from the New York and Washington folios of the U. S. Geological Survey; and the manuscript maps of Dr. Bascom and the writer. The scale of the map has required more or less distortion in the representation of the quartzite and limestones and in the mapping of the rocks of the less metamorphosed western portion of the plateau. The lines must therefore be regarded as only provisional, especially in the areas north of Washington and that part of Pennsylvania which has not been mapped by Dr. Bascom.

General Structural Lines.

The broad structure lines of the Maryland Piedmont, so far as they have been worked out in the eastern or more crystalline portion, are indicated in the accompanying sketch by lines occupying the axes of the synclines and anticlines. It is impossible on any small scale map to represent the minor structural lines, which of course more or less modify the position of the axes of the major folds. It is believed, however,

that the lines here indicated represent the structural characteristics up to the scale of the base employed. The individual axes distinguished in the area are described in greater detail in the following discussion.

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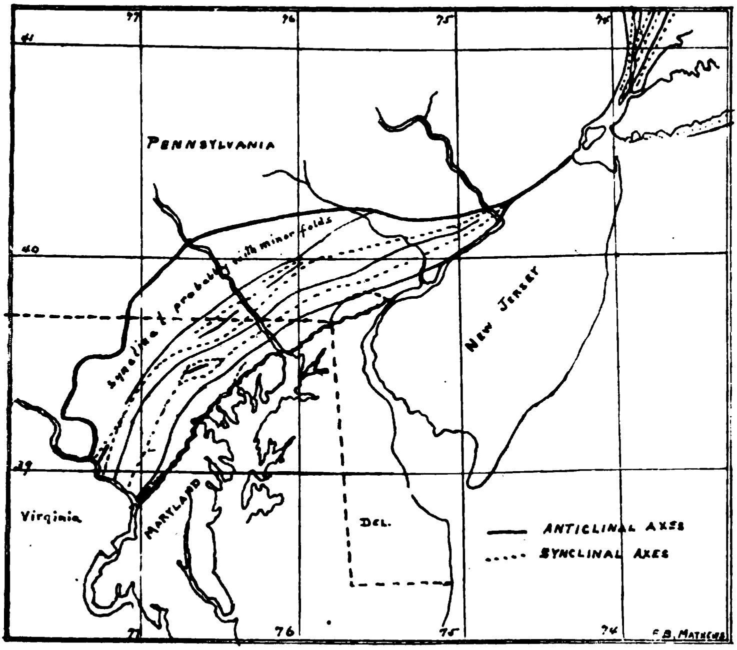

*Structure Lines of the Piedmont.**

East Alexandria–Winters Run Syncline.—Poorly exposed syncline extending from Churchville to east of Baltimore, east of Washington to Alexandria. Covered for the most part with Coastal Plain deposits and largely hypothetical. As shown in Harford county, this axis is plunging southwest.

Washington Uplift–Towson–Belair Anticline—A rather shallow anticlinal axis which may in reality be composed of several minor ones, recognized by Keith as a portion of his West Washington anticlinorium. Occupied for the most part by gabbro sheets on either flank. Probably the line passing from the vicinity of Belair eastward through the central Piedmont district of Cecil county and possibly corresponding to the eastern anticlinal axis suggested by the older gneiss of the Philadelphia

*When the terms "anticlinal axis" and "synclinal axis" are used it is not intended to convey the idea that the lines are of simple structural folds but that these lines represent the dominant axes of anticlinoria and synclinoria. For local points see maps of National and State Geological Surveys.

area. Apparently plunging to the northeast, but this is not clear. These two axes lie within the limits of what are regarded as possibly Archean gneiss areas.

Caves–Forest Hill Syncline.—A well-defined synclinorium extending southward from Scarboro to the area between Green Spring and Worthington valleys in the Baltimore quadrangle. Plunging to the sonthwest. At the Caves the center of this synclinorium is occupied by a small anticline which brings the limestone to the surface. Southward from the Caves the axis apparently extends to the Clarksville–Highlandtown region and probably corresponds to the sag between the two lines of uplift in Keith's anticlinorium. The synclinal basin east of Buck's Ridge, Pennsylvania, may represent a continuation of this general line.

Cabin John–Jarrettsville–Bucks Ridge Anticline.—An overturned anticline beginning west of Jarrettsville on the Taylor Valley road and extending southwestward through Manor and Western Run on the Parkton quadrangle; is probably part of the general anticlinal axis which is represented to the southwest by the imperfectly studied axial line determined in great measure by the strong synclines on either side. It is approximately in the same position as the strong uplift recognized by Keith near Cabin John on the West Washington quadrangle. Eastward from Jarrettsville the anticlinal axis is less marked and is apparently occupied by the long band of serpentine which crosses the Susquehanna river at Bald Friar and extends eastward into Pennsylvania, where it is represented by the Bucks Ridge anticline.

Glencoe Syncline.—A small synclinal axis extending from Glencoe on the Northern Central Railroad southwest through Priceville to Mantua on the Parkton quadrangle and apparently separating the lines of the anticlinal axes on either side, bringing to the surface along Western Run some of the overlying limestone. The structure in this region has not been thoroughly worked out and there may be a small thrust fault.

Cardiff Syncline.—A strongly-marked synclinal basin with its greatest depth in the neighborhood of Cardiff, Maryland. This conforms to the center of the phyllite belt as far as that has been traced. It apparently connects with the synclinal axis recognized by Keith as passing just east of Great Falls. This syncline carries the youngest rocks of this portion of the Piedmont Plateau and has been recognized as a structural feature for many years by the Pennsylvania and Maryland geologists. The bedding in this basin is no more distinct than in the basins and folds previously described, but the presence of the small quartz conglomerate at the base of the slates as well as the slates themselves have made the recognition of its presence

much easier. It seems to be a southern extension of the Chester Valley folding,

Tocquan Anticline.—Tocquan anticline, recognized by Professor Frazer in his report on Lancaster county (CCC, p. 128) as a broad flat anticlinal arch somewhat tilted to the southeast, crosses the Susquehanna river at McCall's Ferry. This structural line has been traced by the Pennsylvania geologists from northern Chester county through Lancaster and York counties to the Maryland line. Throughout this area the axis is complicated by the presence of minor folds. It seems to rise to the north and south. In Maryland the work along this axis has not been carried very far, but the areal distribution of the rocks seems to indicate that it corresponds roughly with the center of the mica-schist zone passing east of Westminster, crossing the Potomac to the southwest of Rockville. The occurrence of interfolded phyllites along the western boundary of the more crystalline part of the plateau, as worked out by Keith, and of phyllites farther south to the west of Gaithersberg, suggests that this axis is here even less strongly marked and that it is broken into several shallow folds.

The region between this anticlinal axis and the overlapping Jura-trias bed on the west appears to be a shallow much-folded synclinorium with an anticlinal axis passing near Union Bridge, Maryland, but this region has not been worked with sufficient detail to warrant more definite statements.

On the eastern side of the Catoctin mountain the Shenandoah limestone rises with an easterly dip from beneath the phyllites and is in turn underlain by the Antietam quartzite and other rocks of Cambrian age.

Character and Distribution of the Igneous Rocks.

The most prominent feature of the igneous rocks is the occurrence of large masses of gabbro in more or less parallel bands, separated for the most part by masses of granite and smaller areas of ancient gneisses. The areal distribution of these gabbro masses, which in the region about West Chester, Pennsylvania, have been found by Dr. Bascom to extend across from one belt to the other, is believed by the author to indicate that the various occurrences represent what was once an immense gabbro sheet extending from Laurel, Maryland, to the Schuylkill river, a distance of fully 85 miles with an exposed breadth of at least 15 miles.

Through this great sheet of gabbro were apparently intruded the granites and later meta-rhyolites and pegmatites, the whole constituting one great series of igneous activity. When these intrusions began or when they ceased is not clearly determinable since contacts between the various rocks are almost

entirely lacking, and any contact metamorphism which they may have imposed upon the rocks existing at the time of their intrusion is now obscured by the subsequent metamorphism which they and the associated country rock have undergone. From the fact that parts of this igneous complex are intruded into the rocks regarded as Silurian in age, this activity could not have ceased prior to the later portion of the Silurian and may have been much later. That the intrusions are not younger than Paleozoic time seems to be an inference well supported by the fact that they along with the sediments partake of the broad folding characteristic of the Appalachian region to the westward, which was probably developed contemporaneously in the rocks of the eastern and western portions of the state. Moreover, the sedimentaries of Jura-trias time show little folding of this type, their deformation being due almost entirely to very gentle folds and small faults of slight throw.

Relation of the Eastern and Western Districts of the Piedmont

The division of the Piedmont Plateau into an eastern division composed of much metamorphosed, highly crystalline rocks, and a western division characterized by less metamorphosed, so-called semi-crystalline, rocks has long been recognized but was first sharply emphasized by the late Professor Williams in 1891. He regarded the eastern area as composed of rocks far more ancient than those in the western district and that they extended westward, forming a floor upon which the younger phyllites were deposited. He also believed that the eastern portion had already been much folded and metamorphosed before the phyllites had been laid down. As conclusive against the identity of age of the semi-crystalline and holocrystalline rocks he summarized the following points.*

a. The structure is not really a synclinal, but a fan-like divergence of dip from a central vertical axis, such as could not be produced by any synclinal bending in a continuous series of similar beds.

b. Any cause altering any part of an original series more than another would not make an *abrupt* contact, such as we find between the semi-crystalline and highly crystalline rocks of Maryland, but a gradual transition.

c. Any cause altering one flank of a synclinal more than the other would make the contact between the two kinds of rock and the axis of the synclinal coincide, as is not the case in Maryland.

d. The eruptive rocks of the eastern area are found in many places in close proximity to the slates or schists, without having effected their alteration; hence they are either not the cause of metamorphism, or they are themselves older than the semi-crystalline rocks; and, moreover, the sudden disappearance of the abundant eruptive rocks at the edge of the western area is itself a strong reason for supposing that it is of later age.

e. We cannot suppose that excessive dynamic action was the cause of the metamorphism, because where we should expect the folding force to have acted equally we find the hardest rocks (eruptives) much more altered, foliated, and disturbed than the soft argillites.

* Bull. Geol. Soc. Amer., vol. ii, 1891, p. 316.

The generalization reached by Williams in this paper is one of far-reaching importance and marked his ability to gain clean-cut conceptions of intricate problems from the most meager investigations. The writer has had occasion to re-examine most of the areas studied by Williams and has been impressed with the grasp of the subject and accuracy of the conclusions drawn when judged by the amount of information at his disposal. It should be borne in mind, however, that at the time this paper was written and even up to the date of Dr. Williams' death, only a small portion of the Piedmont in Maryland had been mapped by the topographers of the U. S. Geological Survey and not all of this had been studied in detail geologically. The generalizations drawn were based upon rapid reconnaissance driving-trips across the Plateau rather than upon detailed examinations carried on throughout the region.

Bearing these facts in mind, it is no serious criticism to Williams when the writer asserts that the detailed work of the last ten years, conducted with greater opportunities and with the aid of topographic maps, shows that the facts on which Williams based his conclusions are not proven. Taking up the five points regarded by him as conclusively proving that a time break exists between the eastern and western rocks, the writer would call attention to the fact that the "fan-like divergence of dip from a central vertical axis" does not seem to be a correct interpretation of the structural lines found within the region, which, on the contrary, indicate that there has been a series of folds rather than a single syncline or fan-like structure. The apparent occurrence of such a structure is due partly, no doubt, to the confusion of true bedding planes with those due to schistosity. The abrupt contact, such as Williams seemed to find between the semi-crystalline and highly crystalline rocks of the Piedmont, apparently does not exist with the sharpness formerly supposed, since Keith's work in Carroll and Howard counties has broken the sharp line drawn by Williams into an intricate series of intertonguing areas. The contact between the so-called phyllites and the gneiss as drawn by Williams is, in most cases, a contact between the phyllites and the mica-schists and gneisses of Hudson age rather than with the banded gneisses believed to represent pre-Cambrian. The contact here, judging from the experience of more recent workers in the region, is not abrupt but is usually obscured by the similarity of material or the likeness of soil resulting from the mica-schists and banded gneisses.

The fact that the igneous rocks of the eastern area when in close proximity to the slates or schists show little metamorphism, may be explained by the fact that within the Maryland

area only relatively small bodies of serpentine and granite come in contact with the younger gneisses and schists, and where such is the case the intrusive body has been so small as to produce no appreciable metamorphism. Moreover, if any contact metamorphism occurred, it would now be practically unobservable since the entire region has been more or less metamorphosed and contacts are almost entirely lacking in fresh rock. "The sudden disappearance of the abundant eruptive rocks at the edge of the western area," as inferred by Williams, is now recognized to be a conclusion not wholly in accord with the facts. Keith in his work in Frederick county found numerous bodies of aporhyolite and metamorphosed acid volcanics and this find has been corroborated and extended by the field work of the writer. In this region of so-called semi-crystalline rocks the eruptives found by Keith and others have been so metamorphosed into sericitic schists that they are scarcely distinguishable from the nearby phyllites except for the presence of small quartz and feldspar phenocrysts.

The points raised by Williams that the contact between the rocks of the eastern and western areas does not coincide with the axis of the syncline and that the eruptives were much metamorphosed at points where one would infer from the structure but little metamorphism, involve the assumption of a rather simple synclinal or fan-like structure which has already been shown to be discordant with the facts as developed by later and detailed investigations.

From the foregoing paragraphs it may be readily seen that the writer does not believe that the points raised by Williams validly disposed of the contemporaneous age of the rocks in the eastern and western portions of the Piedmont. Moreover, the detailed work of Keith on the west and the reconnaissance work by the Maryland Geological Survey on the north, point to an infolding of the various rocks which ultimately may show their similarity in age, when the detailed work has been completed.

Conclusions.

From the past ten years of work in the detailed mapping of the Piedmont rocks of northern Maryland the author has been led to the following conclusions as best in accord with the facts in hand:

1. The older rocks of the Piedmont consist of both sedimentary and igneous types which since their formation have been more or less metamorphosed.

2. The metamorphosed sediments include banded micaceous and hornblende gneisses of pre-Cambrian age; a more or less intermittent thin-bedded generally tourmaline-bearing quartz-

ite of Cambrian age; an intermittent dolomitic marble or magnesian limestone of Cambro-Ordovician age; and a series of mica-shists and the gneisses of Ordovician age. Above these occur a somewhat intermittent poorly developed quartzitic conglomerate and the Peach Bottom slates.

3. The igneous rocks consist of an immense gabbro sheet, intruded by numerous large bodies of granite and meta-rhyolite, and accompanied by numerous more basic serpentinized bodies. These various masses represent stages in a single extended period of igneous activity.

4. The time when this activity took place was later than early Silurian and earlier than the late Carboniferous; probably in the early part of this interval.

5. The chief structural features of the region are the metamorphism and constant schistosity and the broader folding of the different rocks.

6. The metamorphism of the rocks, especially of the banded gneisses, probably commenced prior to the intrusion of the gabbro and granite and was accentuated by them in the eastern portion of the Plateau.

7. The folding of the region is of the Appalachian type, the rocks occurring in several long, more or less parallel folds, with few faults and but occasional overturned folds.

8. The eastern and western areas are probably of the same age; differences in metamorphism being due to the large bodies of deep-seated intrusives on the east and the smaller bodies of surface volcanics on the west.

9. The sequence found in Maryland may be recognized from Washington to Trenton and in the region north of New York.

If these conclusions are confirmed by later investigation, it will be necessary to modify the generally accepted hypothesis of a former mountain range along the eastern Atlantic now represented by the Piedmont Plateau; or the location of this hypothetical range, which is supposed to have supplied the sediments for the Appalachian sea during Paleozoic time, must be shifted, at least for the earlier Paleozoic, farther east where its roots would not lie buried under Coastal Plain deposits.

Johns Hopkins University, November, 1903.

ART. XII.—*Direct Micrometric Measurement of Fog Particles;* by C. BARUS.

1. *Introductory.*—Before using the data computed for the dimensions of fog particles in the reductions of my observations of atmospheric nucleation,* it seemed expedient to endeavor to obtain corroborative values by some straightforward method. Aitken's dust counter had naturally suggested itself early in the course of my work; but the results so obtained are essentially indirect as the fog particles are not themselves observed. It was necessary, therefore, to devise apparatus by which the identical fog particles of a given corona could be directly entrapped and held for examination. This was eventually accomplished in a way admitting both of the measurement of the diameters of the particles and, probably, of counting the number precipitated under known conditions. Moreover, the particles caught, however fine (even less than $\cdot 0003^{cm}$ in diameter), can be kept in place for observation, so that microscopic photography is applicable not only for the purpose of obtaining size but (possibly) number.

Many investigations are thus suggested, as, for instance, a repetition of Thomson's method for determining the charge of an ion; an experimental test of the subsidence equation for small spherules, etc. Again, while the corona gives merely the average size of the cloud particles, the microscope is particularly available for indicating variations of diameter for the particles of the same corona. In fact, the water particles when caught are not of a size; they are graded and hence the nuclei are probably also graded in size.

2. *Apparatus.*—Aitken's beautiful and highly ingenious instrument† is well adapted for the work for which it was designed; but it will not subserve the present purposes. Aitken's droplets evaporate too rapidly in spite of their artificially increased size. The need of mixing atmospheric air and dust-free air with shaking and stirring is an interference with the nucleation. In fact, water nuclei may even be generated in this way, possibly by the friction of air passing across damp surfaces. There is the tendency of the plate after long use to fog permanently or to collect droplets on its own account. Finally, it would be very difficult to remove the contents of the coronal chamber to the dust counter without changing the nucleation during the transfer.

I therefore endeavored to ascertain whether the particles

* Phys. Review, xvii, p. 233, 1903; cf. ibid., xvi, 193, 246, 1903.

† My thanks are due to Mr. A. L. Rotch, who was good enough to lend me his dust counter.

might not be made visible directly. The chances of success seemed small indeed, in particular as Assmann* had failed to see the particles with the magnifications of even 400 diameters. But after long trial, the result was eventually accomplished in a way that now seems surprisingly simple.

The compound microscope, *M*, magnifying about 100 diameters, is provided with a filar ocular micrometer, *n*. The objective and the whole lower part of the microscope is submerged in the condensation chamber, being suspended for this purpose from the wide rubber cork, *C*. All lenses below *C* are hermetically sealed with wax. The microscope originally carried a rigid stem, *r*, to which were then attached the plate, *s*, to be examined, the mirror *m*, and the metallic disc or shield, *d*. Afterwards the more flexible adjustment shown in the figure and described below was adopted. The lower side of *p*, which is flush with the objective, and the upper side of *s* are covered with wet blotting paper, the latter being perforated to admit light into the microscope through the thin cover glass placed at *s* and held sharply in focus by a suitable clip. The field within which drops are to be counted is bounded at pleasure by the wires of the micrometer.

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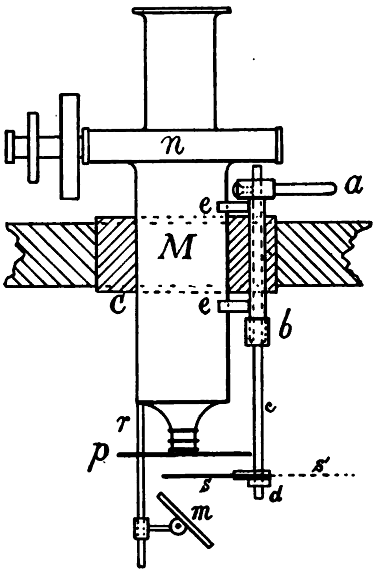


This apparatus was totally unsuccessful. Drops were but rarely seen to fall on exhaustion, while the dew soon gathered on the plate *s*, in such a way as to be easily mistaken for droplets; for the dew evaporates like the latter when the microscope is removed, and the regularity of the pattern on the plate is the only distinguishing feature.

Various modifications of this apparatus were then used, among them capsule forms similar to Aitken's, but containing a very thin plate of glass or mica or celluloid slightly raised above the base on pellets of wax. It was supposed that this would counteract the tendency of the drops to vanish by evaporation from the warmer glass surface. Capillary metallic

* Cf. Arrhenius, Kosmische Physik, vol. ii, p. 487, 1903.

tubes led to the "curl" aneroid, the filter, and to the cock for influx of air, the only large tube being the exhaust pipe. Condensation again occurred as a microscopically granular deposit spontaneously on the raised surface, under all circumstances, and the experiments were failures. After oiling the raised filmy mica surface, however, droplets were often seen to fall and either to stick fast or to float. These could at times be counted (2000–5000 per cub. cm.); but the rapid evanescence of precipitated droplets and the failure of all attempts to reach systematic results induced me to abandon the capsule.

I therefore returned to the apparatus in figure 1, using at s a plate of thin microscopic glass covered with a film of oil and exposed in the capacious vacuum chamber. The experiments were now phenomenally successful. Thus for the aperture $s = 5$ the mean results were $n = 150{,}000$, and for $s = 4{\cdot}6$ (w g b p), $n = 140{,}000$. The precipitation of globules was clearly seen and they persisted even after the exhaustion was removed. The numbers being excessive and referable to globules swept in by lateral air currents, an improvement was now added by increasing the diameter of the disc p to about 5^{cm}. The improved apparatus gave no results whatever, and the mere addition of the wider disc wiped out all precipitation. But this capricious behavior is characteristic, for next day with a smaller disc drops were seen to fall as follows:

$s = 4{\cdot}5$	w g b p	$n = 6{\cdot}5 \times 10^4$
$4{\cdot}6$	w g b p	$4{\cdot}7$
$6{\cdot}3$	w g b p	$13{\cdot}3$

after which no precipitation could be caught in the six subsequent exhaustions by the identical method. The same unaccountable irregularity was noted in the afternoon. Next day again the first experiments showed

$s = 6{\cdot}0$	w c g	$n = 7{\cdot}3 \times 10^4$
$6{\cdot}4$	w g v p	$12{\cdot}4$

after which further precipitation did not occur.

The apparatus was then again modified to the final form shown in figure 1, by inserting a thin brass tube laterally through the stopper C, and firmly soldering this tube at e above and below to the body of the microscope. A rod snugly fitting the tube thus provided an eccentric focussing device, $abcd$, with a stuffing box at b, and an external handle at a. The latter is adjustable by aid of a set screw so that the plate s may be kept in focus during rotation of the rod. To catch the droplets, the plate s is rotated into the position s' quite beyond the shield, p, for a time (15—30 seconds) and then returned to s for examination. In this way the definite

results were obtained, in a manner to be further detailed below, with the apparatus free from capricious behavior. It is of particular interest that the particles caught on the oiled surface persist as brilliant round globules for a long time (10 min. or more) in a saturated atmosphere. They very gradually vanish as a rule, on the readmission of air into the condensation chamber.

To remove the globules for the next experiment the influx of air is thus not generally sufficient. It is necessary to withdraw the microscope from the condensation chamber bodily and to wave it about a few times in dry air. On returning it to the chamber the plate is then again clean and white.

At first the plate was oiled by a small flat piece of blotting paper saturated with oil and held on a stem, care being taken to remove all excess. Clean machine oil or ordinary illuminating oil, or a mixture of the two, subserved the purpose about equally well. Probably the best method of oiling consists in dipping the plate rotated outward to s' in very hot melted vaseline (to drive away moisture), removing the excess while hot by filter paper, and when cold submerging the plate in petroleum for transparency. With solution of vaseline in benzine, etc., I have been less successful.* A film of varnish dried and soaked in turpentine was used. When drops are to be counted by the method given below, the oil film must be practically solid; otherwise the capillary forces produce an immediate and often startling redistribution of the precipitated granules, though they may not coalesce.

3. *Behavior of the precipitated droplets.*—In case of a petroleum film on the plate, the water droplets were sometimes seen to fall and float on the film, which is positive evidence against spurious droplets. They are usually black and circular in outline, but when the light is intense and axial, they are often colored. Fixed globules were apt to be larger and more irregular and pink or red in color. The color was eventually traced to the chromatic aberration of the objective used. This defect was rather useful in detecting clear globules, but it would be fatal in photography.

On tipping the microscope so that the light does not penetrate the vividly colored drops axially, they seem to cast shadows in opposed directions for symmetrical inclinations on both sides, as in fig. 2; but the phenomenon is probably a case of refraction† with the shadow beginning at the edge of a dis-

* It has thus far been difficult to produce an oily film free from flaw and quite glossy under the microscope, where surfaces are apt to be either reticulated or fluid.

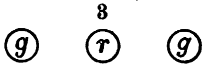
† That the effects described are associated with the aplanatic foci of spheres (as I at first supposed) is improbable. The globules lie on the oil film through which nearly parallel light enters. The caustic is not shown in fig. 2.

tinctly visible caustic. Similarly on moving the lamp horizontally to either side from the position corresponding to vivid pink color, fig. 3, and axial illumination, the globules become opaque and look like round shining steel beads. The diameter of the beads has but little effect on the axial or the other color.* If the lamp is moved until the field is dark, the plate looks like the starry heavens. These "stars" or foci are seen to be above the drops. They should lie (roughly) ·0003/·33 to ·0015/·33^{cm} above it.

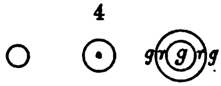
2

After remaining in the plate for some minutes the fixed droplets often become rosette-shaped (apparently), at first (fig. 4) showing a mere black spot in the center of the color disc which gradually enlarges to a ring-shaped appearance *slowly moving radially outwards*. As a rule, the color is eventually the same on the inside and the outside of the enlarged ring, the ring itself appearing red with black demarcations in the surrounding green field as shown in the figure. On influx of air the structure becomes washed. The small globules when at first deposited never show the same color within and without, the former being uniformly red and the latter white. As the rings are not easily produced with a very viscous oil, it is

3



4



probable that the droplet has here penetrated to the glass and that the oil film is drawn over it by the capillary forces at the common edge of the three media. But the cause of the radial expansion is an interesting subject for conjecture.

4. *Preliminary measurements.*—Before adopting the eccentric focussing device, many experiments were made to ascertain the cause of the uncertainty in catching the drops on the plate when kept in place, seeing that sometimes the precipitation was abundant, while at other times, under the same apparent conditions, drops did not fall. Failures occurred both for high and for low nucleation. From the outset it was improbable that radiation from the outside could affect the result. It was eventually ascertained that on tipping the con-

* The degree of transparency will depend on the amount of contact of the globule and the oil film, and the floating globules are therefore sometimes quite opaque, at other times partially or wholly transparent.

densation chamber, after the fog had formed so that the subsidence would reach the plate obliquely, a precipitate would usually appear. Again, an oblique current within the chamber and passing across the plate usually produced a deposit. Hence, as the drops actually exist within the fog, success in bringing them down upon the plate is conditioned by very close isothermal adjustment of the plate to its surroundings, added to the advantages gained from incidental and favorable air currents. Thus a little time must always elapse before the drops persist at the plate, and therefore the droplets from a shallow capsule do not appear. Using a film of mica as a plate the result was the same, and it is useless to attempt to enumerate the drops by this method. Those which fall are carried in by grazing air currents, while no drops are obtained from the fiducial space under the objective. Cf. § 5.

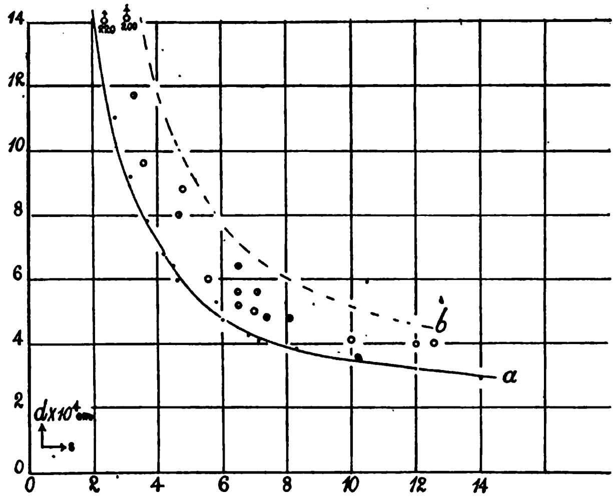
Nevertheless, the measurement of the diameters, d, of the drops obtained by the given method without modification is an excellent test of the results obtained elsewhere by computation. The factor of the ocular micrometer described above was $\cdot002^{cm}$ per turn of the screw or $\cdot00004^{cm}$ per scale part of the drum divided into 50. The extent of plate covered by the breadth of the spider lines was about $\cdot0003^{cm}$. The finest particles are of about this diameter, so that such measurements must at best be much inferior to photography with a scale attachment. I will pass over the tabulated results here, merely stating that the coronal color with its diameter, s (chord of a radius of 30^{cm}), was observed when the eye and the source of light (Welsbach mantel seen through a small circular hole) were at distances 85^{cm} and 250^{cm}, respectively, from the center of the condensation chamber. The exhaustion was usually to a pressure difference of 17^{cm}, but this is of no significance when diameters are alone to be measured. The particles were collected by tipping the chamber, sometimes in large numbers, but at other times sparsely distributed without apparent cause. Nuclei were conveniently obtained from burning charcoal. Both floating and fixed globules were examined with strong microscopic illumination. It was difficult to retain a clear image without frequently removing the plate as the adjustment for focussing the plate within the chamber had not yet been adopted.

Floating globules were sometimes observed in the act of coalescing; but this is much rarer than the passage of a floating droplet* over a fixed one without interference. A distinct central red area, shading off into darkness, was seen even in the floating globules when axially illuminated by intense light. The larger drops were often metallically green. The colors

*Multitudes of fog particles are often seen moving in opposite directions across the field and turning about normally at the edges of a liquid film.

(chromatic aberration) vanish after long standing and they are particularly vivid immediately after falling. It was not even now possible, in spite of all precautions in tipping the vessel, to obtain an abundant crop of drops at pleasure.

If the results are given graphically in a chart in comparison with the computed data of my earlier experiments* as well as with my later† experiments, the observed results lie below the



latter where adiabatic conditions were assumed, and above the more recent experiments where the effect of the successive expansions was computed isothermally. In other words, the observed diameters were intermediate but nearer the older results.

5. *Number of droplets.*—The following results were obtained with the definite form of apparatus shown in figure 1. A method of estimating the nucleation from a direct count made under the microscope is obtained as follows: Let the plate s be rotated to s' so as to catch the descending fog particles for a definite interval of time, t. If v be their velocity of subsidence, all particles within a height, h, will be caught, if

$$h = vt \qquad (1)$$

and

$$v = 10^6 d^2/3{\cdot}24 \qquad (2)$$

where the usual value of the viscosity of air has been inserted. Furthermore, m grams are precipitated per cub. cm. by the given exhaustion, and if n be the nucleation

$$n = 6\,m/\pi d^3 \qquad (3)$$

* Phil. Mag. (6), iv, p. 24, 1902. See curve b in the following chart.
† This Journal (4), xvi, p. 325, 1903. See curve a in the following chart.

Finally if c is the area of the field seen in the microscope and n' the number of particles falling into this field

$$n' = n\,h\,c \qquad (4)$$

From these equations n is obtained by eliminating v as

$$\sqrt[3]{n} = \frac{2{\cdot}11 \times n'}{t\,c\,m^{2/3}\,10^{6}}$$

The values of the constants usually adopted were $t = 30$ sec., $c = 144 \times 10^{-6}$ sq. cm., $m^{2/3} = 2{\cdot}8 \times 10^{-4}$, whence $\sqrt[3]{n} = 1{\cdot}75 \times n'$.

The experiments to test this method often gave serviceable results some of which are inserted in the following tables; but at times the n-values are out of proportion The reason of this is three-fold: In the first place n is found from $n^{1/3}$ with the usual difficulty. Again, in a simple arrangement like the above, air currents cannot be quite excluded. They may arise incidentally in the apparatus, or the motion of the plate even, if parallel to itself, may stir the air unless some form of guard ring attachment is added. Particles are thus swept down

TABLE I.—Observed diameters (d) of cloud particles and numbers (n) per cub. cm. $m = 4{\cdot}7 \times 10^{-6}$ g per cub. cm.; micrometer factor ·00004^{cm}. Distances of goniometer and light from condensation chamber, 85^{cm} and 250^{cm}; chord s for radius 30^{cm}. Exhaustion to $\delta p = 17^{cm}$.

	s	corona.	$c \times 10^6$	t	n'	n observed.	n computed.	d observed.	d computed.
	cm.		cm.^{2}	sec.				cm.	cm.
	....	olive	140	30	37	270000	250000	....	....
	6·0	w r g	140	30	27	105000	90000	....	....
Phosphorus nuclei....	10·2	w o b g'	70	30	17	210000	210000	·00036	·00036
	7·4	w p b g	70	15	6	....	....	48	41
	7·1	w' b p	....		..	....	....	56	42
	4·7	corona	....		..	....	....	80	61

Particles as small as ·0003^{cm} present throughout.

Do.	6·5	g b p	140	15	10	43000	100000	·00064	·00046
	6·5	g' b p	....					56	46

Particles graded as usual.

Air Nuclei .	4·5	corona	140	15	9	30000	40000	·00064	·00064
	6·5	g' b p	....		..	....	....	52	46
	8·1	w c b g'	70	15	14	120000	150000	48	39
	8·2	Do.	70	15	16	180000	150000	....	39

Particles graded as usual.

upon the disc before and after the exposure, as was actually observed. The difficulty may be removed by adding a capsule above the plate or simply by decreasing the distance between the shield and the plate to a millimeter or less. Finally if the oil film is semi-fluid and not quite fixed, if there is slight creeping as was often the case, the particles are redistributed after falling along stream lines where they cohere in strings and bunches, usually without coalescing. This was also observed, and in fact the capillary forces involved are apt to be strong enough to counteract viscosity.

6. *Data.*—I have not thus far spent much time in correcting these defects, chiefly because the new results for the diameters of fog particles are more immediately interesting. Some data are given in Table I.

If the diameters measured are plotted in a chart, together with the results computed from successive exhaustions and coronal aperture s in the older (curve b) and in the more recent (curve a) experiments, the present values again lie between the two curves but now nearer the lower (recent) curve than before, § 4. I shall not pause to interpret the differences which remain, but only to remark that the capillary forces at the area of contact of the droplet, even with the liquid oil film, may transform it to an oblate spheroid and that diffraction at the circular edges of the drops is not excluded. Micrometric data cannot be smoother because the particles are not of a size for the same corona. If the nucleation n_0, obtained from successive isothermal exhaustions and subsidence measurement, be accepted as correct (lower curve a), the ratios of the nucleation found from the different methods tested will be

From subsidence, $a = \cdot 0029$,	$d/d_0 = 1\cdot 0$	$n/n_0 = 1\cdot 0$
from lycopodium ($d = \cdot 0032^{cm}$), $a = \cdot 0034$,	" $= 1\cdot 2$	$n/n_0 = \cdot 61$
from diffraction (blue), $a = \cdot 0034$,	" $= 1\cdot 2$	$n/n_0 = \cdot 61$
from micrometer measurement, $a = \cdot 0037$,	" $= 1\cdot 3$	$n/n_0 = \cdot 48$
old results (adiabatic conditions assumed),	" $= 1\cdot 6$	$n/n_0 = \cdot 24$

Since n is obtained from the cube of d, large differences of this kind are as yet inevitable, particularly as the particles measured in these different cases are not the same.

7. *Graded nuclei.*—The point of special interest which comes out on using the eccentric plate to catch the subsidence during 15 or 30 seconds, and at once examining the deposit, is the result that particles of all sizes are present. By far the greater number, however, have the maximum diameter. These particles are caught from the fog without interference and it is not probable that coalescence or evaporation have been appreciably operative, so long as the corona remains the same throughout the micrometer measurement. The probable

explanation is this: while the pressure decrement is growing from zero to the maximum δp, condensation is taking place on the greater number of particles throughout the whole of this interval. In other words, although the nuclei are graded in size, the greater number exceed a certain dimension and require almost no pressure decrement to induce condensation. These are the particles (diameter exceeding a certain inferior limit) which give character to the *persistent* corona. A minority of the graded particles are below the dimension in question and upon these condensation does not take place until the higher values of the pressure difference are reached, some may even require the full pressure decrement, δp. Thus it is that in the deposit of fog particles, one finds those of diameter $\cdot001^{cm}$ intermixed with others of smaller diameter, even as far as $\cdot0002^{cm}$ or less. When fresh phosphorus nuclei are first introduced into the condensation chamber the result is a grey fog, but a relatively small white reddish corona is nevertheless discernable. Accordingly the crop of droplets seen under the microscope contains not only surprisingly small but also relatively large droplets, with all intermediate diameters. Hence the indefinite fog and the small corona. The large olive (g b p) corona and other of the early coronas are very apt to *fade* into a coarse white reddish corona. This is the evaporation of the smaller particles into the larger, which accounts moreover, for the loss of nuclei during the first precipitation, to be caught in subsequent exhaustions. The successive coronas in a series gradually become sharper and the larger particles more uniform, but extremely fine particles are still present even when one approaches the normal coronas. The fine particles, however, belong to coronas so large and diffuse that their coronal effect scarcely modifies the strong coronas of the large particles, even before the former vanish by evaporation.

When I first observed these different sizes of drops caught on a single plate, it seemed not improbable that a difference of the condensational effect of the negative and the positive ions might here be actually in evidence; but as all intermediate sizes are present at the outset, and particularly as large and small droplets still appear together long after all electrification has certainly vanished, this conclusion is not warranted. What continually favors uniformity is subsidence of fog. As the phosphorus nuclei are graded, it is probable that the very fine droplets are due to the initial or primitive nuclei from which the larger nuclei have grown by cohesion; or the fine droplets may be due to air nuclei associated with the phosphorus nuclei. All this will appear in a more minute photographic study of the subject with which I am now engaged, and it will then be further interesting to decide whether the nuclei generated

by the X-rays are not also graded below a certain usually much smaller maximum diameter, and, in general, to ascertain where the nuclei originate. That this maximum diameter will increase with the lapse of time allowed for coherence may be inferred from my experiments with the steam jet: X-ray nuclei will not act upon the steam tube unless a certain time is allowed for growth, as I understand it. The coarse and washed type of coronas obtained with nuclei produced by the X-rays is evidence of graded size, while the fog particles, so far as I have yet caught them, are of varied dimensions. In these cases the X-rays reached the inside of the condensation chamber through its waxed wood walls lined with wet cloth. To obtain a fairly strong and large corona an exposure to the rays lasting 5 to 10 minutes was needed, as the radiation was not very intense. In this interval the original extremely small nuclei are probably undergoing continuous growth, for instance by cohering, so that on exhaustion particles of all sizes* are revealed. In addition to the ragged coronas there is copious rain.

* Under these circumstances it seems reasonable that the time loss of nuclei must at the outset be proportional to the square but finally to the first power of the number, assuming that eventually the large nuclei do most of the catching.

Brown University, Providence, R. I.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Formation of Ozone.*—When an electric discharge was passed in a tube of fused quartz evacuated to a few millimeters of mercuric pressure, it was noticed by E. Goldstein that an intense odor of ozone was produced in the vicinity of the quartz tube. Potassium iodide and starch paper were quickly made blue by the product. The odor disappeared instantly when the discharge was interrupted. The phenomenon appeared when the gas pressure in the tube was varied rather widely; it was most intense when the light from the tube was brightest. Narrow tubes were found to be preferable to wide ones for the purpose. No odor of ozone was perceptible when glass tubes were used in place of those of quartz. The author believes that the phenomenon is due to the action of ultra-violet rays of very small wave-length, which pass through the quartz glass and convert the oxygen of the air into ozone.

When a U-shaped quartz tube, through which the discharge was passing, was dipped into liquid air, noticeable ozonization did not appear to take place. It is possible that the ozone in the air surrounding a quartz discharge-tube might have been condensed by cooling, but it seemed preferable to make the experiment with oxygen inside of a tube where the production of ozone would probably be greater. Experiments showed that it was possible to convert oxygen entirely into ozone within a Geissler's tube, which, in this case, was made entirely of glass, by cooling a portion of the tube with liquid air and admitting oxygen from time to time in proper quantities. The cooled part of the tube quickly became coated with a blue layer of liquid ozone. When the tube was removed from the liquid air the blue liquid ran down the walls of the tube and collected at the bottom as a blackish-blue liquid. When a part of the tube was kept cool with liquid air the pressure within the tube fell to about $\frac{1}{10}^{mm}$ and this pressure remained constant as long as liquid ozone was present, even when the tube was pumped out as far as possible. This indicated that all of the oxygen was converted into ozone and it showed the tension of ozone at the temperature of liquid air. No spontaneous explosions of the liquid ozone took place during these experiments, such as were observed by Ladenburg when ozone was condensed under atmospheric pressure.—*Berichte*, xxxvi, 3042. H. L. W.

2. *A Peculiar Property of Some Hydrated Salts.*—A. de Schulten observes that, as a general rule, where salts form several hydrates, the hydrate richest in water gives the lower hydrates by successive increases in temperature. For instance, $MgSO_4 \cdot 12H_2O$, at a few degrees above freezing is changed to $MgSO_4 \cdot 7H_2O$, while at 52° $MgSO_4 \cdot 6H_2O$ is formed, and at 132°

$MgSO_4 \cdot H_2O$ is produced. Many other cases of this usual manner of transformation are known. The peculiarity to which attention is called is the behavior of certain hydrates which do not act in the usual way in this respect. Three examples are given. Gay-lussite, $CaCO_3 \cdot Na_2CO_3 \cdot 5H_2O$ loses the whole of its water at 100°, while pirssonite, $CaCO_3 \cdot Na_2CO_3 \cdot 2H_2O$, does not undergo any change at 100°, and it is only at a temperature of 130° that it loses the whole of its water. The compound $Mg_3(PO_4)_2 \cdot 22H_2O$, at 100°, quickly loses 18 molecules of water, and then very slowly loses more water, while artificial bobierrite, $Mg_3(PO_4)_2 \cdot 8H_2O$, does not undergo any alteration at 100°. The arseniate $Mg_3(AsO_4)_2 \cdot 22H_2O$, corresponding to the above phosphate loses 17 molecules of water very quickly at 100°, while artificial hoernesite, $Mg_3(AsO_4)_2 \cdot 8H_2O$, does not change at all at 100°.—*Bulletin*, xxix, 724. H. L. W.

3. *Attempts to Prepare Nitrogen Fluoride.*—Several years ago it was announced by Warren that he had prepared a fluoride of nitrogen in oily drops by the electrolysis of ammonium fluoride solution. Moissan failed to produce any such compound by the action of fluorine either on nitrogen or ammonia. RUPP and GEISEL have recently attempted to prepare the compound by Warren's method, and by other methods which suggested themselves, and after an elaborate series of experiments were unable to obtain any evidence of its existence. It seems probable that Warren used ammonium chloride, and that the explosive body obtained by him was merely nitrogen chloride.—*Berichte*, xxxvi, 2677. H. L. W.

4. *Quantitative Chemical Analysis;* by the late DR. C. REMIGIUS FRESENIUS. Authorized Translation of the Sixth German Edition by ALFRED I. COHN. 2 vols., 8vo, pp. 780 and 1255. New York, 1904 (John Wiley & Sons).—This voluminous work is apparently an absolutely complete translation of the last German edition, which appeared in 1875, twenty-nine years ago. The translator has made a number of additions. In the first part, which is the systematic treatment of the subject, the additions are practically confined to those introduced by Johnson and by Allen, and to be found in the last American edition of 1881. It is to be noticed, however, that modern atomic and molecular weights have been substituted for older ones throughout the work. The second or special part of the book contains occasional additions by the translator of modern methods, and as appendices are added the methods of analysis adopted by the Association of Official Agricultural Chemists, and also Hillebrand's treatise on Rock Analysis.

It is to be regretted that the translator abandoned his original intention of inserting many of the more recent and improved methods of chemical analysis, for space might have been gained for these by the omission of the antiquated methods thus supplanted; but the reverential attitude of the translator was evidently such that it seemed improper to omit anything. However,

it should be observed that a large part of the inorganic analysis of thirty years ago is applicable at the present time, and that this classical work of Fresenius must still be considered the standard reference book on the subject. H. L. W.

5. *The Analytical Chemistry of Uranium;* by HARRY BREARLEY. 8vo, pp. 45. London, 1903 (Longmans, Green & Co.).—This little book deals chiefly with the author's experience in determining uranium, in separating it from the associated elements, and in descriptions of analyses of uranium minerals. In view of the present importance of uranium ores as sources of radium, it seems remarkable that this interesting metal is not mentioned in the book under consideration in the list of elements occurring in pitchblende. It is still more remarkable that the author apparently is not familiar with the discovery of helium, for he mentions nitrogen as a constituent of pitchblende and refers only to Hillebrand's work on this subject. H. L. W.

6. *Chemical Calculations;* by H. L. WELLS. 8vo, pp. 58. New York, 1903 (Henry Holt & Co.).—The first thing noticed on opening this book is the excellent arrangement of the logarithm tables, which are provided with a thumb-index and are exceedingly convenient for such calculations as a chemist usually has to make. There is a table of gravimetric factors for calculating analytical results which is very complete, and a convenient set of tables to be used for gases. Also, a table for calculating indirect analyses, and another to be used in calculating fluxes to form slags. The second part of the book explains briefly, with examples, how the tables are used. H. W. F.

7. *Solar Radiation and the Pressure of Light.*—This subject is discussed in an important paper by Professor POYNTING of the University of Birmingham. The author takes the fourth power law, $R = \delta\theta^4$, where R is the energy radiated per sec. per cm. by a full radiator at temperature θ°A (A stands for the absolute scale) and δ is the constant of radiation. According to Kurlbaum

$$\sigma = 5 \cdot 32 \times 10^{-5} \text{ erg.}$$

Taking the various values given by different observers of the solar constant, Poynting calculates the effective temperature of the sun, and places it between 6000° A and 7000 A—more exactly at 6200° A. The effective temperature of space is then 10° A. If a body, therefore, is raised to a small multiple of 10°—say 60°—the fourth power law of radiation implies that it is giving out and, therefore, receiving from the sun more than a thousand times as much energy as it is receiving from the sky. The sky radiation can, therefore, be left out of account, when we are dealing with approximate results, and bodies in the solar system may be regarded as being situated in a zero enclosure except so far as they are receiving radiation from the sun.

On the supposition that the moon does not conduct inward, its upper limiting temperature is found to be 371° A, just below the temperature of boiling water. Langley estimated the tempera-

ture of the moon to be a few degrees above the freezing point. On the supposition that three-fifths of the heat is conducted inward, Poynting calculates the upper limit at 297° A. He also calculates the temperature of fully absorbing spherical bodies of 1^{cm} in diameter at the distance of the earth from the sun and finds the temperature $\theta = 300°$ A. This will be the temperature of bodies smaller than 1^{cm}, so long as they are not too small to absorb all the radiation falling upon them. The variation of temperature with distance from the sun is next estimated; the author regards it as highly probable that the temperature of mass is everywhere below the temperature of freezing point of water. The only escape from this conclusion is to suppose an appreciable amount of heat issuing from his surface. Considering a comet as made up of small particles of the order 1^{cm} or less, these particles twenty-three million miles from the sun would have the temperature of melting lead, and at three and three-quarters million miles, the temperature of cast iron (1500°).

Poynting then discusses the value of the radiation pressure. Bartoli showed that a pressure must exist without any theory in regard to the nature of light, beyond a supposition that a surface can move through the ether, doing work on the radiation alone, and not on the ether in which the radiation exists. The most interesting part of the paper is that which deals with a comparison between mutual gravitation and radiation pressure of small bodies. Poynting calls attention to the fact, that if the radiating body is diminished in size the radiation pressure due to it also decreases less rapidly than the gravitative pull which it exerts. The radiation decreases as the square of the radius of the emitting body and its gravitational pull as the cube. It is also noted that equality of action and reaction does not hold between the radiating and receiving bodies alone. The ether is material and takes its part in the momentum relations of the system. Two globes of water, probably nearly full absorbers at 300° A, will at that temperature neither attract nor repel each other if their radii are about 20^{cm}. Small particles of the order 1^{cm} radius would be drawn into the sun even from the distance of the earth in times not large compared with geological times. Near the sun the effects are vastly greater. The application to meteoric dust in the system is obvious. The entire paper pleads for an extension of our idea of matter to include the medium. Bodies do not act upon each other; each sends out a stream of momentum into the medium surrounding it. Some of this momentum is ultimately intercepted by the other, and in its passage the momentum belongs neither to one body nor to the other. The action on one of the bodies is equal and opposite to the reaction on the light-bearing medium contiguous to it.—*Phil. Trans. of Roy. Soc.*, Series A, vol. ccii, pp. 525–552. J. T.

8. *Blondlot's n-rays.*—BLONDLOT describes a new species of rays which he terms *n*-rays. These rays are given out by the Auer-burner or still better by the Nernst lamp. They penetrate alumi-

num: are absorbed by the smallest layer of water: acting like long heat waves. While they are absorbed by cold platinum they easily penetrate red-hot platinum. These n-rays radiate from the Nernst lamp long after this lamp is extinguished, and silica exposed to the sun's rays show these rays.

Dr. O. Lummer calls attention to the physiological effects on the retina produced by experiments similar to those of Blondlot, and suggests that the n-rays are merely ghostly images produced on the structure of the retina and its nerves by the method of observation pursued by Blondlot. The phenomena observed by the latter appear to be the result of the struggle between the rods and cones of the retina in the effort to fix our vision in the dark.—*Deutsch. Physikalisch. Gesellsch.*, v Jahrg., Nr. 23. J. T.

9. *The Rowland Effect.*—The magnetic effect of electric convection has been tested by Wilson, Adams and Pender and Eichenwald. In addition to these investigators is now Himstedt, who publishes a quantitative investigation in the hope of adding cumulative evidence. One series of trials gave for the value of v, the ratio of the electrostatic to the electromagnetic units, 3·04; and a second series, 2·99. Himstedt's experiments, therefore, confirm Rowland's results.—*Ann. der Physik*, No. 1, 1904, pp. 100–123. J. T.

II. Geology and Natural History.

1. *United States Geological Survey.*—The following publications of the U. S. Geological Survey have recently been received:

Monograph XLV. The Vermilion Iron-Bearing District of Minnesota, by J. Morgan Clements. 447 pp., 13 pls., 23 figs., 26 atlas sheets. This is the fifth of the monographs published by the Survey which deal with the geology of the various iron-producing districts of the Lake Superior region. The ore deposits, which make the region of great interest, are strikingly like those of the Marquette district. The ore bodies are usually found either at the bottom of a highly folded chert or jasper formation and resting upon an underlying igneous mass folded into a synclinal trough, or within the iron-bearing formation and resting upon intercalated silts or intruded dikes of igneous rock. The mode of origin assigned to the ore bodies is the same in general as that given for the other districts, and which has been described in detail by Van Hise in the monograph on the Penokee district.

The monograph is well illustrated and is accompanied by an atlas giving detailed maps of the area. A useful feature is the introductory outline, which gives a brief summary of the matter treated in the book. W. E. F.

Bulletin No. 211. Stratigraphy and Paleontology of the Upper Carboniferous Rocks of the Kansas Section, by George I. Adams, George H. Girty and David White. 123 pp., 1903. The area covered is situated in Eastern Kansas, and represents

exposures of a continuous series of beds; sandstones and shales and interbedded limestones, of 3250 feet thickness. An erosional unconformity limits them below, somewhere in the lower part of the Upper Carboniferous, and the uppermost formations are regarded as Permian.

Forty-seven distinct formations are recognized, giving an average of about seventy feet to a formation. No attempt is made by the author to form more comprehensive divisions of the whole, as was done by Haworth and by Prosser, since the sedimentation is found to be continuous, oscillating between sets of dominantly calcareous beds and sets of beds dominantly shaly, the fossils occurring more richly in the limestone or calcareous formation. "*The evolution of the latest from the earliest faunas*," is said, by Girty, to be "*without marked interruption at any point so that subdivisions appropriate for recognition are not clearly apparent.*" No classification of the beds seems to be especially favored by the evidence of invertebrate paleontology.

David White reports on the Plants from the Kansas beds and finds the majority of them typical Coal Measure (Pennsylvanian) species, while those from the Marion and Wellington formations at the top of the section, identified by Sellards, indicate Permian age. H. S. W.

Folio No. 94. Brownsville-Connellsville folio, Pennsylvania, by Marius R. Campbell. This geological map and its explanation is an admirable example of the thorough work produced by the Survey. The region covered is in southwestern Pennsylvania, in the midst of rich coal and gas fields. The survey is based upon triangulation surveys, and topography of the surface as well as the underground structure are elaborated in detail. Numerous stratigraphic sections of mines (92 are figured and described) are given and the productive horizons of numerous gas wells determined. The classification of the formations is the usual one, with the thickness for this region as follows, viz:

? Permian	Dunkard	300′
Pennsylvanian	Monongahela	310–400′
	Conemaugh	600′
	Allegheny	280′
	Pottsville sandstone	150′
Mississippian	Mauch Chunk	150′
	Pocono	400′

The Pocono sandstone is at its top developed into a siliceous limestone. In the midst of the Mauch Chunk, the Greenbriar limestone is developed as a lentil from 0 to 30 feet thick, fossiliferous; it is shown to be of Chester age. An unconformity is recognized at the base of the Pottsville, the lower member of which is believed to represent the Conoquenessing sandstone. In the Conemaugh formation a crinoidal limestone (the Ames limestone), four feet thick, is seen below the Morgantown sandstone.

The upper Coal Measures (Monongahela) contains the important Pittsburg, Redstone, Sewickly, Uniontown and Waynesburg coals. Between the Sewickley and Uniontown the so-called "great limestone" occurs to which the name Benwood limestone is applied. Many productive gas wells are scattered over the Brownsville quadrangle, statistics of which are given. H. S. W.

2. *On the Geology of the Hawaiian Islands;* by WM. H. DALL. (Communicated.)—In the article by Dr. Branner on the Geology of the Hawaiian Islands, in the October number of the Journal, he comes (pp. 306–309) to a different conclusion with regard to the calcareous layers interstratified with the tuffs of Diamond Head, Oahu, from that to which I was led in 1899. This difference is probably due to the fact that Dr. Branner did not see all the area which I examined and reasoned from certain beds which he did see and which are doubtless of a different nature from those to which I referred.

I found oysters, *Chama*, and numerous corals, fossilized as they grew, and still adhering to the nearly horizontal surface of the continuous thin sheet of lava which formed the basis of an area of very considerable extent entirely outside of the slope of the tuff cone but apparently continuous under it. The particular horizon which I examined formed the top of the ground for a considerable distance inland, and the circumstances are entirely incompatible with the idea of a subaërial formation. That there may be subaërial formations around Diamond Head in some places is highly probable, but that is another story.

Smithsonian Institution, Washington, D. C., Dec. 15, 1903.

3. *Geological Commission, Cape of Good Hope;* G. S. CORSTORPHINE, Director. Annual Reports, 1900, 1901, 1902.—The geological work for 1900 was mainly in the district west of the Karroo plateau. A new formation (the "Ibiquas Series") is reported lying between the Malmesbury beds and the Table Mountain sandstone. Glaciated pebbles were found in the Table Mountain series (early Devonian). The underlying unconformity of the Dwyka conglomerate (this Journal, xiii, 413) is changed to conformity at the south. Dolerite sheets and dikes cut the Paleozoic sediments. Announcement is made of the discovery of a new Mesozoic swimming reptile.

Owing to the Transvaal war, the geologists of the Commission spent the season of 1901 along the southeast coast line making a general survey of Transkei and Pondoland with special studies of the Cretaceous of Pondoland and of the igneous rocks (granite, diorite, dolerite) of Kentani. The map shows a remarkable adjustment of streams to the diorite. During 1902 Mr. E. H. L. Schwartz made a survey of parts of the Matatiele Division in Griqualand East. Perhaps the most interesting part of his work is the description of a row of 19 volcanic necks trending northeasterly, from which issued the lavas which form the crest of the Drakensbergs. The cones and flows are deeply eroded or destroyed on their east (wet) side but are well preserved on their west side.

"The sedimentary rocks through which the chimney is pierced never show the least shattering or plication." A petrological examination of these volcanics (pp. 65–96) shows them to be dolerites and basalts. The common type is the "amygdaloidal melaphyre" with long, narrow branching vesicles as first described by Cohen (Neues Jahrbuch, 1875). Mr. A. W. Rogers was appointed acting geologist in 1902, and, in addition to his official duties, surveyed parts of Beaufort West, Prince Albert and Sutherland Divisions. A classification of strata has been adopted for Cape Colony which in outline is as follows:

Superficial Deposits.	Dunes; Alluvium, Laterite, Esturine and River Deposits.
	Pondoland Cretaceous Series
	Uitenhage Series
Karroo System (Permian Jurassic ?)	Stormberg Series
	Beaufort Series
	Ecca Series
	Dwyka Series
Cape System (Devonian ?)	Witteberg Series
	Bokkeveld Series
	Table Mountain Series
Pre-Cape Rocks In the south and west of Cape Colony	Ibiquas Series
	Congo Series
	Malmesbury Series
Pre-Cape Rocks In north and northwest of Cape Colony	Matsap Series
	Griqua Series
	Campbell Rand Series
	'Kreis Series
	Namaqualand Schists ?

The vertebrate fossils from these series are now being examined by Professor Seely; the plants by Mr. Seward; the invertebrates by Mr. Lake, Mr. Kitchen and Mr. Chapman. Until these fossils are reported on, correlation will not be attempted.

It is to be regretted that suitable maps and sections do not accompany these reports.

4. *Geological Society of South Africa* (Transactions, vol. vi, parts 1, 2, 4).—The most recent publications of the Geological Society of South Africa contain papers by E. P. Rathbone on the Geology of the DeKaap Goldfields; by J. P. Johnson on sections at Shark River and the Creek, Algoa Bay; by G. S. Corstorphine on the age of the Central South African Coalfield; by G. A. F. Molengraaff on the Vredefort Mountain Land. The Vredefort region consists of a granite intrusion with zones of metamorphosed sediments. In part 4 are papers by J. P. Johnson, on the Discovery of Implement-bearing beds near Johannesburg in which Eolithic, Palaeolithic and Neolithic forms are described; by A. R. Sawyer on the Origin of the Slates on the Rand and on the Vredefort Granite Mass; by F. H. Hatch on the Black Reef Series; by J. Kuntz on Pseudomorphosis of Quartz Pebbles into Calcite.

5. *The Action of Radium, Roentgen Rays and Ultra-Violet Light upon Minerals and Gems.*—An article by G. F. KUNZ and C. F. BASKERVILLE upon this subject is given in full in the issue of Science for Dec. 18, 1903. A number of minerals, including diamond, willemite, kunzite, pectolite, topaz, fluorite, autunite, etc., were subjected to these different forms of radiation and a considerable part found to respond. Of these, willemite, the violet-colored spodumene called kunzite and diamond were the most responsive to all forms of activity; the possibility of the presence of some undetermined element with the willemite (also hydrozincite, etc.) is suggested. In the case of minerals from Borax Lake, California, of different composition but which all phosphoresced with ultra-violet light, though not with radium, the existence of an element explaining this property is also suggested. The whole subject is one calling for much additional investigation.

6. *Optical Characters of Anthophyllite: a Correction;* by C. H. WARREN. (Communicated.)—The writer wishes to make a correction regarding the optical orientation of the anthophyllite from Rockport, Mass., described in this Journal, vol. xvi, November, 1903, p. 341. The orientation should be: $c' = \mathfrak{c}$, $a = \mathfrak{a}$, $b = \mathfrak{b}$, thus making the mineral optically negative.

The error was due to the fact that a quartz wedge was used in making the determinations, which was cut with the vibration direction of fastest ray opposite to that of this ray in the wedges to which the author had always been accustomed. Until very recently no occasion had arisen to use this particular wedge for the determination of a known mineral and so the error remained unnoticed.

7. *Chemical Composition of Igneous Rocks expressed by means of Diagrams;* by J. P. IDDINGS. U. S. Geol. Surv. Professional Paper, No. 18, Washington, 1903, 4°, 92 pp., VIII pl.—The author of this paper was one of the first petrographers to express the chemical relationships of igneous magmas, revealed in their chemical analyses, by graphic means. In recent years we have seen this instrument used by different petrographers in a variety of ways to develop special features, but never before has it been employed with so great a breadth of scope and on a plan so comprehensive as in the present work. The idea is to express pictorially to the eye the mutual chemical relations of all analyzed igneous rocks. For this purpose a double diagram method is used. Each analysis has its molecular ratios calculated and these are referred to a system of axes, and the points on the axes connected with each other by lines. The triangles thus formed are tinted with different colors and this enables the eye at a glance to perceive the relations of the molecular oxides and their capacity for forming feldspathic and ferromagnesian molecules. These are the individual diagrams. The small individual diagrams so formed are then placed in a very large diagram in which their centers or zero points are referred to a set of rec-

tangular axes in which the abscissas are the percentages of silica and the ordinates are the ratios obtained by dividing the molecular proportions of the combined alkalies by the molecular proportions of the silica. This point forms the locus of the small diagram.

In the first table are given the small colored diagrams of over 950 analyses of igneous rocks having over 28 per cent of silica, selected to show all possible variations. The table is continued and completed in plate viii, which shows the rocks with less than 28 per cent of silica. In another table are shown the loci of the alkali-silica ratios of over 2000 analyses; in this case the individual diagrams are omitted and the loci shown by simple dots. In other plates are shown the diagrams of analyses, disposed as in plates i and viii, divided and arranged according to the new quantitative chemical classification recently proposed by Cross, Iddings, Pirsson and Washington.

There are many interesting and instructive features shown by these diagrams which must be seen to be appreciated. Perhaps the most convincing thing they prove is the impossibility of any "natural" classification of igneous rocks and that any division lines must of necessity be wholly arbitrary ones.

The work is certainly a tribute to the patience and industry of the author, a reflection that is forced home when one thinks of the vast number of analyses that have been computed and carefully arranged in these diagrams. Whatever evidence they present certainly does not lack weight for want of facts to sustain it. L. V. P.

8. *Petrographisches Prakticum;* von R. RHEINISCH. Part II, Gesteine. Pp. 180, 8°. Berlin, 1904 (Gebr. Borntraeger).—The first part of this work has been previously noticed in this Journal (vol. xiii, p. 243, 1902). The object of this elementary treatise is to afford help to the beginner in the study of rocks; it is not intended as a complete text-book and its use demands some previous acquaintance with the elements of the science. The igneous rocks, the sedimentary rocks and the crystalline schists are briefly treated. The "dike rocks" are not assigned a separate position but are mentioned under the abyssal granular types. The system of classification followed is essentially that of Zirkel. Each rock is briefly described, its mineral composition mentioned, a few mass analyses given and the more important localities, especially the German ones, stated. The book is well gotten up and appears carefully written and will no doubt prove useful in Germanic countries. The thought that strikes one in connection with it is, that since a knowledge of the subject and the use of the microscope are implied, why not use one of the larger textbooks at once in which all phases of the subject are covered and more information given. L. V. P.

9. *Les Roches alcalines caracterisant la Province pétrographique d'Ampasindava;* par A. LACROIX. Nouv. Archiv. du Muséum, 4 ser., v, 4°, pp. 171–254, pl. 14, 1903.—It will be

recalled that some time since Professor Lacroix published an important memoir upon an interesting series of alkaline rocks from the northwest coast of Madagascar as noticed in this Journal, vol. xiv, page 396, 1902. In the present work a new series of similar rocks from other localities in the same province is described with analyses by PISANI, syenites, foyaites, tinguaites, monzonites, etc., which thus extend the limits of this petrographic province in a most interesting way. L. V. P.

10. *Notes on the Rocks of Nugsuaks Peninsula and its Environs, Greenland;* by W. C. PHALEN. Smithson. Misc. Coll. Quart. Issue, vol. xlv, pp. 183–212, 1904.—A petrographic description accompanied by analyses of rocks collected in 1897 by Messrs. Schuchert and White. The rocks are mostly granular crystallines, granite, syenite, diorite, etc., and there is a complete description of the iron-bearing basalt. The work is carefully done and adds to our knowledge of the petrography of the northern lands. L. V. P.

11. *Monograph of the Coccidæ of the British Isles;* by ROBERT NEWSTEAD. Volume I, 1901; pp. xii+220; text figures 20; 39 plates. Volume II, 1903; pp. 270; text figures 7; 42 plates. London (printed from the Ray Society).—The second and final volume of Mr. Newstead's careful and very praiseworthy monograph of the British scale insects has just been published. The entomological monographs published by the Ray Society have not always been of the first rank, but this one of Mr. Newstead's deserves very great praise. Many of these Ray Society monographs have been devoted to the consideration of the fauna of the British Isles, and from its title this would seem to be of equally limited scope. As a matter of fact, the author has only included species which have actually been found living in Great Britain and Ireland, but with the Coccidæ the conditions are such that a far more general interest attaches to this monograph than any of the others which have been geographically so limited. Perhaps the majority of the Coccidæ of the world have, through the constant interchange of plants, become practically cosmopolitan. It is difficult with the majority of species at this late date to decide the probable original home. The result is that by far the larger number of species treated by Mr. Newstead have been introduced into Great Britain, and have established themselves there. To illustrate the interest which American investigators will have in this monograph, of the thirty-six species of Diaspinæ treated in volume i, thirty occur also in the United States, and, of the remaining six, three have been found only in greenhouses in Great Britain and are probably species introduced from some other part of the world. Compared with the world fauna in the Coccidæ, however, the number of species treated in the monograph is, of course, small, and hence some of the generalizations made by the author as to generic distinctions and those of higher groups will possibly be open to criticism when larger series are studied. It seems to the writer, for example,

that an error has been made in confusing the species of the true genera Diaspis and Aulacaspis, since the arrangement of the dorsal tubular spinnerets in the female has been used as the striking character with these and some allied genera, rather than the more important structural characteristics of the anal plates. Some day I fear there will be a general untwisting of Mr. Newstead's assignment of the species of this genera.

An important contribution to the literature of the much-discussed male of *Lecanium hesperidum* occurs in volume ii, and Mr. Newstead describes the second stage and the puparium of what is undoubtedly the true male of this species. He indicates that the male, as was quite to be expected, belongs to the true Lecanium type, and that the alleged discovery by Moniez had probably reference to one of the Chalcidid parasites which universally infest females of this species.

The many illustrations, and especially those upon the plates, all done by Mr. Newstead himself, are better done than any figures of Coccidæ which have heretofore been published.

The revised nomenclature of the Coccidæ, as displayed by Mrs. Fernald in her Catalogue of the Coccidæ of the World, and which must probably be accepted, is not followed in the text proper, but in an appendix to volume ii it receives proper recognition.

L. O. HOWARD.

12. *Catalogue of the Lepidoptera Phalænæ in the British Museum*, Vol. IV. Catalogue of the Noctuidæ; by SIR GEORGE F. HAMPSON. Pp. xx, 689, with an accompanying part containing plates lv–lxxvii. London, 1903.—The issue of Part IV of the British Museum Catalogue of Moths will be welcomed by all interested in this subject. It contains descriptions of some 1200 species of the Agrotinæ, the first of the fifteen sub-families of the Noctuidæ. The plates, reproduced by trichromatic photography, are very beautiful and show the perfection to which the process has been brought.

13. *General Zoology;* by C. W. DODGE. 482 pp., 379 figs. (American Book Company.)—Professor Dodge has revised and re-arranged "Orton's Comparative Zoology" in a way which is highly satisfactory to the teacher and to the general student.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *American Association.*—The fifty-third meeting of the American Association for the Advancement of Science was held at St. Louis during the week from December 26, 1903, to January 1, 1904. Dr. Carroll D. Wright was President of the meeting. The address of the retiring president, Dr. Ira Remsen, was delivered on December 28th, on the subject "Scientific Investigation and Progress." This address is given in the issue of Science for January 1 and the following numbers of the same periodical give a full account of the proceedings. Affiliated societies to the number of twenty-one held meetings in conjunction with the

Association. The total attendance, including 81 in the societies, was 466. The new policy of holding winter meetings, with its obvious advantages and disadvantages, was upheld and the next meeting appointed for Philadelphia, beginning Tuesday, Dec. 27, 1904. New Orleans was recommended for the meeting two years hence. The following officers were elected for the Philadelphia meeting:

President: W. G. Farlow, Cambridge, Mass. *Vice-Presidents:* Section A, Alexander Ziwet, Ann Arbor, Mich.; Section B, W. F. Magie, Princeton, N. J.; Section C, L. P. Kinnicutt, Worcester, Mass.; Section D, D. S. Jacobus, Hoboken, N. J.; Section E, E. A. Smith, University of Alabama; Section F, C. Hart Merriam, Washington, D. C.; Section G, B. L. Robinson, Cambridge, Mass.; Section H, Walter Hough, Washington, D. C.: Section I, M. A. Knapp, Washington, D. C.; Section K, H. P. Bowditch of Boston. *General Secretary*, Charles S. Howe, Cleveland, Ohio. *Secretary of the Council*, C. A. Waldo, Lafayette, Indiana.

2. *Carnegie Institution of Washington, Year Book, No. 2, 1903.* Pp. lix, 311. Washington, January, 1904 (published by the Institution).—This second volume from the trustees of the Carnegie Institution will be widely welcomed since all the facts in regard to the administration of this fund cannot but be of great interest to every one concerned with the progress of scientific research of the country. It is a matter of general congratulation that this unique work has been initiated and thus far carried on with so much liberality and wisdom. The opening part of the volume (pp. i–lix) contains administrative matters including the minutes of the Board of Trustees, the Report of the Executive Committee on the work of the year and memorials of Abram S. Hewitt, William E. Dodge and Marcus Baker. Following this are a series of seven papers including reports on southern and solar observatories, reports relating to geophysics, original memoirs in several departments.

The list given of the grants, aggregating nearly sixty, made during the year out of the sum of $200,000 set apart by the Trustees at its last annual meeting, shows the wide range of scientific inquiry aided by the Carnegie Institution; with each statement a brief account of the results thus far obtained is included. It is interesting to note that the demand upon the funds of the Institution is much greater than it can meet; thus it is stated that from the beginning until Oct. 31, 1903, the total number of requests for aid was 1,042 and these called for an expenditure of $2,200,398. To this sum are to be added the grants recommended by the Advisory Committee aggregating $911,500, thus giving a total possible expenditure of $3,111,898. Although but a small part of the demands for assistance in research can be favorably acted upon, the total amount of good that may be expected from the money actually paid out is very large indeed.

3. *Physikalisch-chemisches Centralblatt.*—The first number of the Physico-chemical Review, announced on p. 475 of the last

volume, has recently been issued under date of December 15, 1903. It contains thirty-two pages and gives seventy-nine abstracts, of physical and chemical papers, in German, French or English, according to their original source. It is much to be hoped that this new review may meet with the general coöperation and support which it deserves.

4. *A Description of the Brains and Spinal Cords of Two Brothers dead of Hereditary Ataxia;* by LEWELLYS F. BARKER. The Decennial Publications of the University of Chicago, First Series, Vol. X, 38 pp., 4to, with twelve plates. Chicago, 1903. (The University of Chicago Press.)—This memoir gives the results of an examination, in part microscopic, of the brains and spinal cords of two brothers, who died of hereditary ataxia. These were cases XVIII and XX of the Series in the family described by Dr. Sanger Brown, who gives here a clinical introduction. Twelve plates with forty-six figures follow the text.

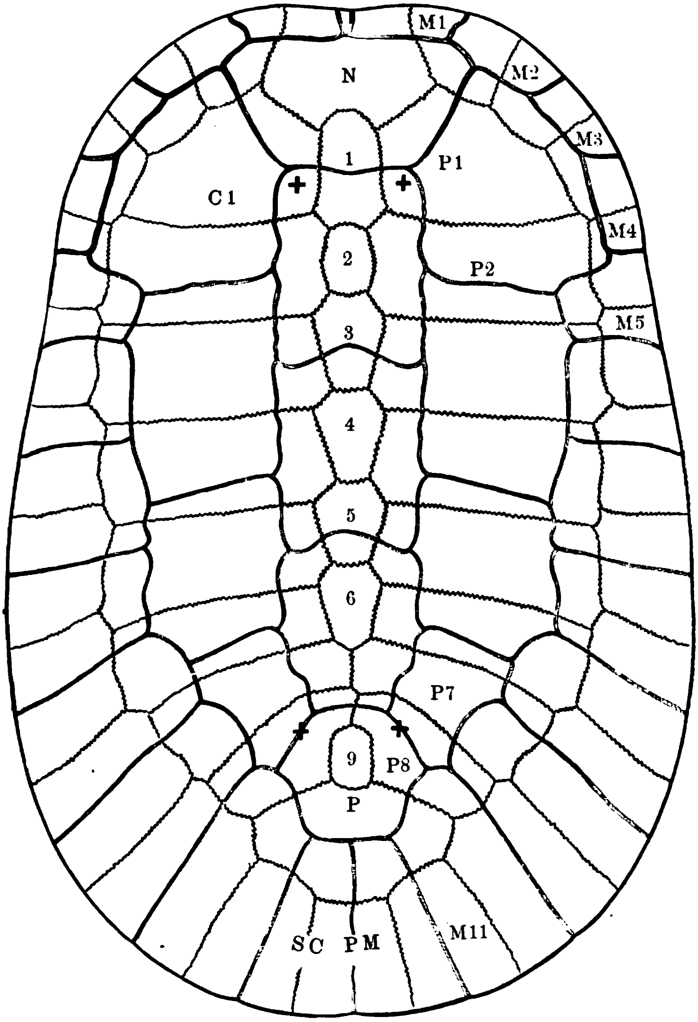
5. *Field Columbian Museum.* — Publications 79, 80 of the Zoological Series, Vol. III, Nos. 12, 13, have recently been issued. The former, pp. 199–232, contains a list of mammals collected by Edmund Heller in Lower California, with descriptions of apparently new species. The latter, pp. 233–237, gives descriptions of apparently new species of *Heteromys* and *Ursus* from Washington and Mexico. Both papers are by D. G. Elliot.

6. *The Planetary System;* by F. B. TAYLOR. 268 pp. Published by the author, Fort Wayne, Indiana.—If Newton's solution of the problem of three bodies were correct it ought to yield a general law for the stability of inner satellites. His analysis, however, shows only indeterminate stability. The theory presented by Mr. Taylor is claimed to yield a law of determined stability of satellites and hence a logical theory for the structure and growth of the solar system.

7. *Metallic Ornaments of the New York Indians;* by W. M. BEAUCHAMP. Pp. 120. Albany, 1903. (New York State Museum, F. J. H. Merrill, Director: Bulletin 73, Archæology 8; Bulletin 305 of the University of the State of New York.)—The number and diversity of Indian ornaments here described will surprise and interest the reader not previously informed on the subject. Upwards of four hundred figures on thirty-seven plates are required for adequate illustration.

8. *Queries in Ethnography;* by A. G. KELLER. 70 pp. (Longmans, Green & Co.)—Professor Keller has prepared an admirable list of queries by use of which observations of travelers and missionaries may be made with such accuracy and pertinency as to be of definite scientific value.

Knowledge Diary and Scientific Handbook for 1904, containing original descriptive articles on the camera applied to science in Astronomy, Microscopy, Natural History; practical work with a small telescope; some uses of the microscope; practical meteorology; the optical constants of lens combinations, and Monthly Astronomical Ephemeris, etc. Pp. 1–420, 85–108. Issued in conjunction with "Knowledge." London (Knowledge Office, 326 High Holborn).



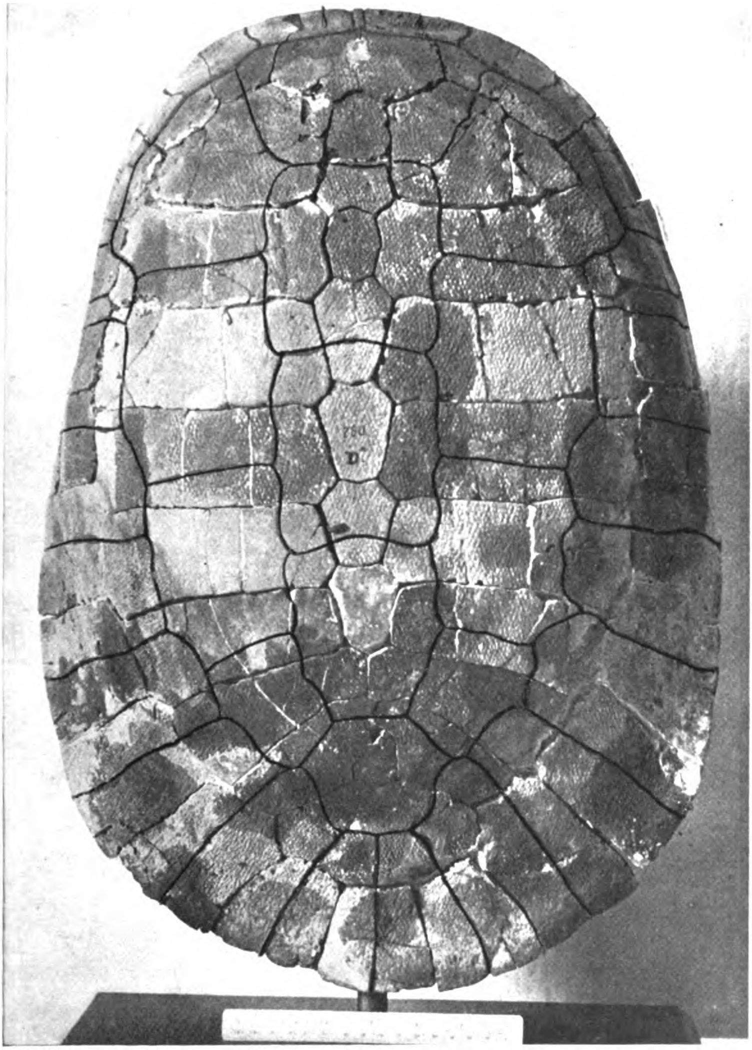
CARAPACE OF ADOCUS PUNCTATUS Marsh, × ½.—Drawn from type.

(a) Bone Plates.—N, Nuchal; 1–6, 9,–1st–6th, and true 9th Neuralia; P, Pygal; Pm, Pygal Marginal; P1, P2, P7, P8,–1st, 2d, 7th and 8th Pleuralia; M1–M5, M11,–1st–5th and 11th Marginals.

(b) Horn Shields.—N and 1, 1st Vertebral; 2 and 3, 2d Vertebral, etc.; C1, the 1st of the four Costals; M1–M5, 1–5 Marginalia; SC, supra caudal.

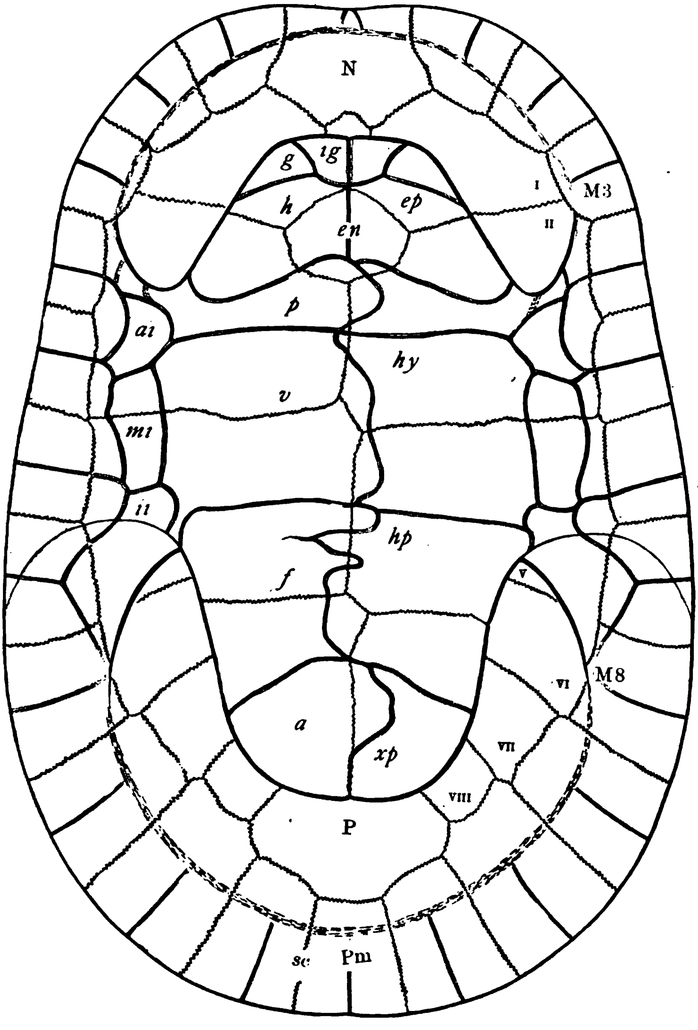
(+) Anterior, point at which the first and second ribs unite with 1st Pleural.

(+) Posterior, point at which rib of tenth dorsal vertebra unites suturally with the 8th Pleural, or else point of iliac support.



CARAPACE OF ADOCUS PUNCTATUS Marsh (type).

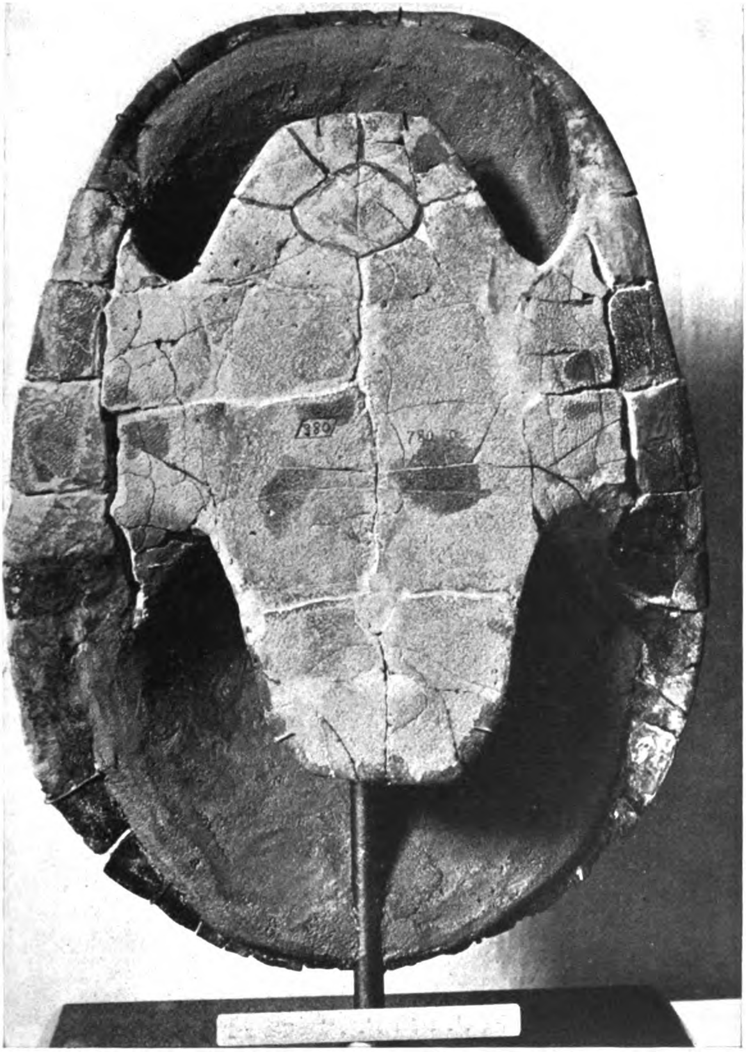
(Actual length, 54 cm.)



Plastral view of Adocus punctatus Marsh, × ½.—Drawn from type.

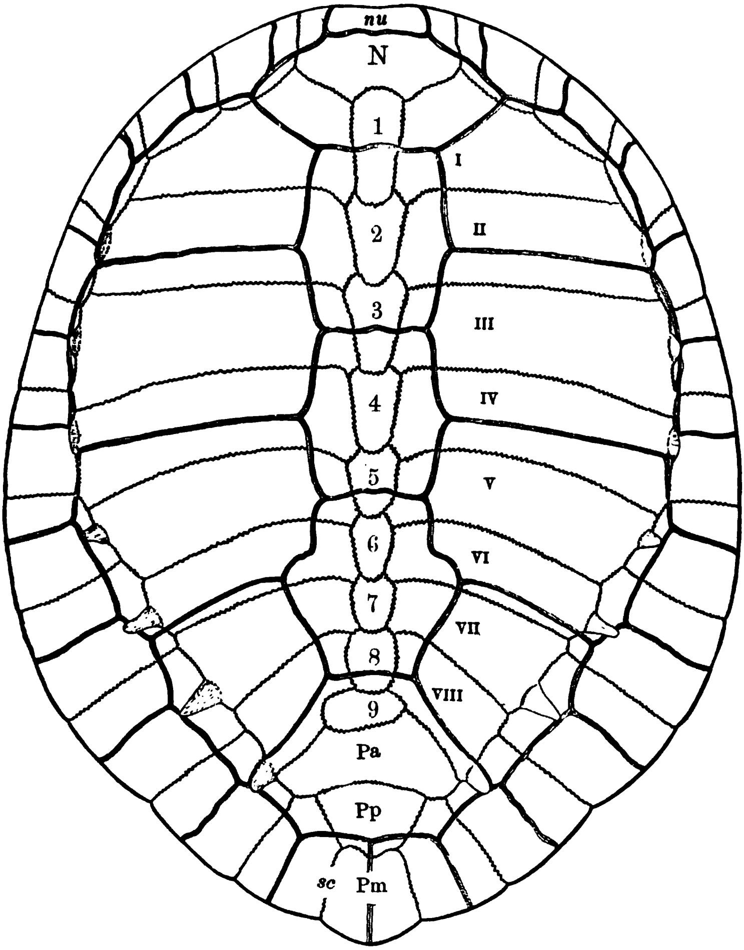
Plastron.—(a) Bone Plates:—*ep*, Epiplastron; *en*, Entoplastron; *hy*, Hyoplastron; *hp*, Hypoplastron; *xp*, Xiphiplastron. (b) Horn Shields:—*ig*, Intergular; *g*, Gular; *h*, Humeral; *p*, Pectoral; *v*, Ventral; *f*, Femoral; *a*, Anal; *ai*, *mi*, *ii*, axillary, mesial and inguinal infra-marginals.

Carapace.—M3, 3d Marginal supporting axillary buttress of Plastron; M8, 8th Marginal supporting inguinal buttress of Plastron; N, Nuchal; P, Pygal; Pm, Pygal Marginal; I, II, V–VIII, 1st, 2d, 5th–8th Pleuralia; *sc*, supracaudal horn shield.



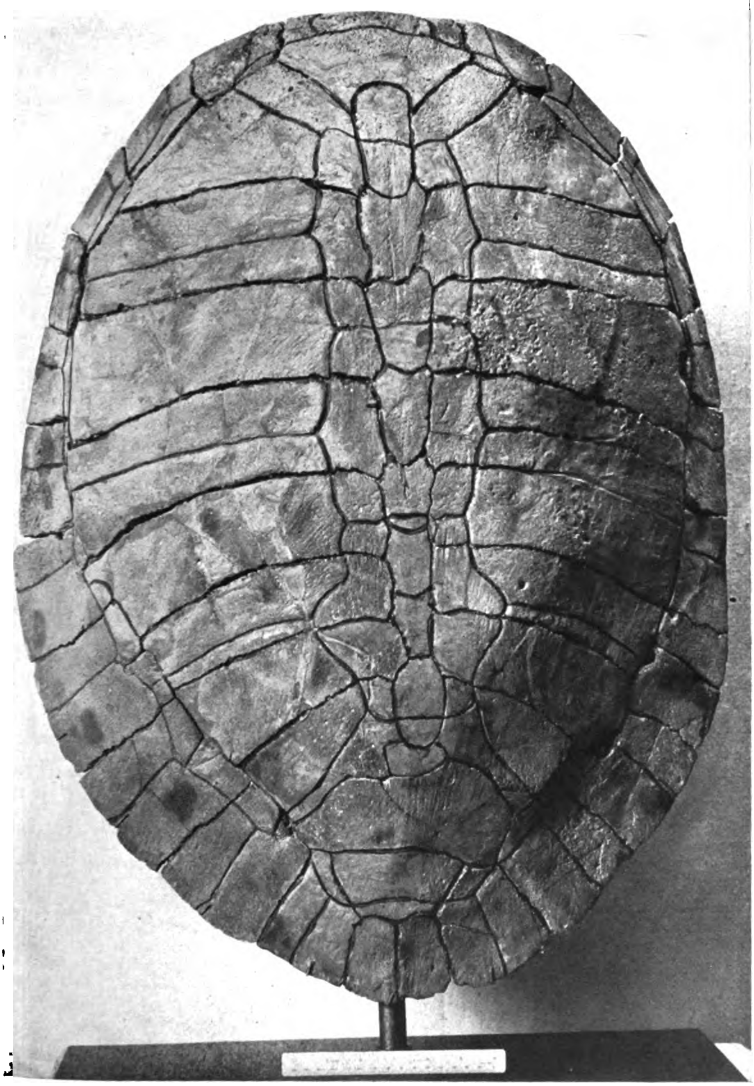
ADOCUS PUNCTATUS Marsh.

Plastral view of type.—Entire length of specimen, 54 cm.

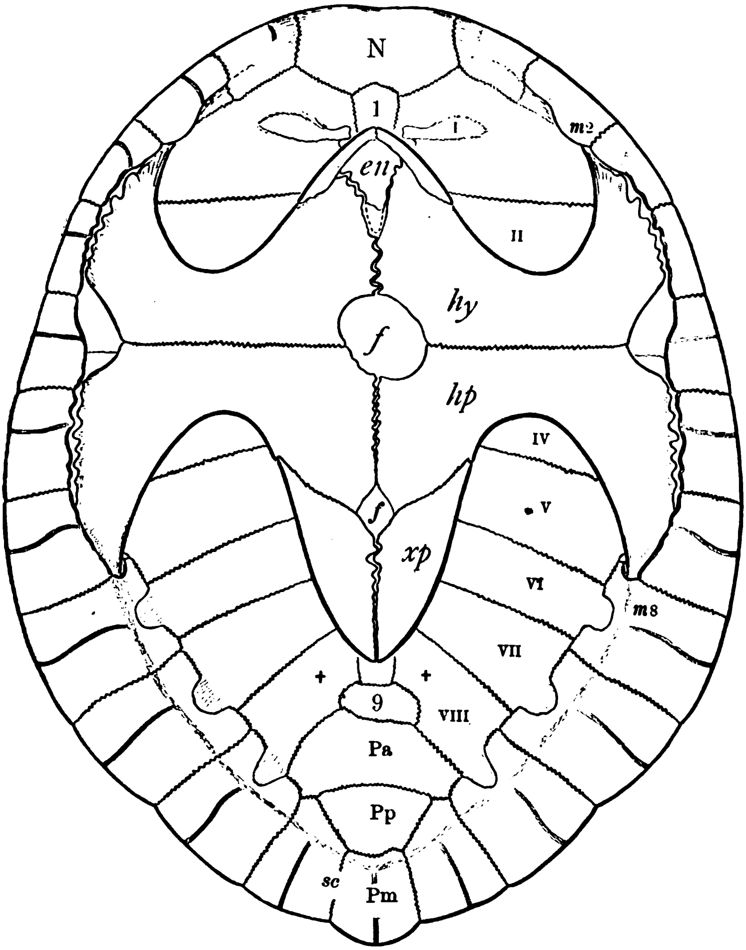


CARAPACE OF OSTEOPYGIS GIBBI Wieland, × ⅙.—Drawn from type.

N, Nuchal: 1-9, 1st-9th Neuralia; Pa, Pygal, anterior; Pp, Pygal, posterior; Pm, Pygal Marginal; I-VIII, 1st-8th Pleuralia; *nu*, nuchal horn shield; *sc*, left supracaudal horn shield.—Bony plates in saw-tooth, and horn shields in triple line border.

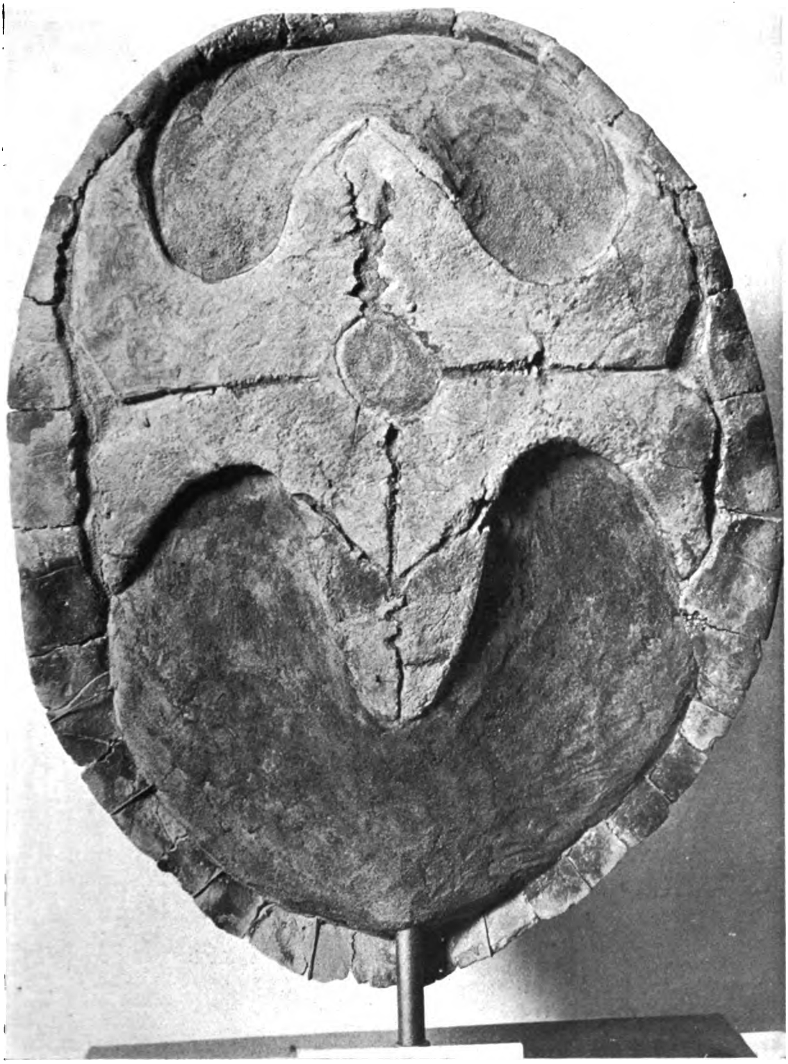


Carapace of Osteopygis Gibbi Wieland (type).
Actual length, 74.3 cm.



PLASTRAL VIEW OF OSTEOPYGIS GIBBI Wieland, × ⅛.—Drawn from type.

en, Entoplastron ; *hy*, Hyoplastron ; *hp*, Hypoplastron ; *xp*, Xiphiplastron ; *f*, *f*, Plastral Foramina ; *m*2, axillary buttress and 2d Marginal ; *m*8, inguinal buttress and 8th Marginal ; N, Nuchal ; 1, 9, 1st and 9th Neurals ; Pa, Pygal, anterior ; Pp, Pygal, posterior ; Pm, Pygal Marginal ; I, First Rib ; II, IV–VIII, Pleuralia ; (+), point of iliac support on 8th pleural ; *sc*, supracaudal horn shield.

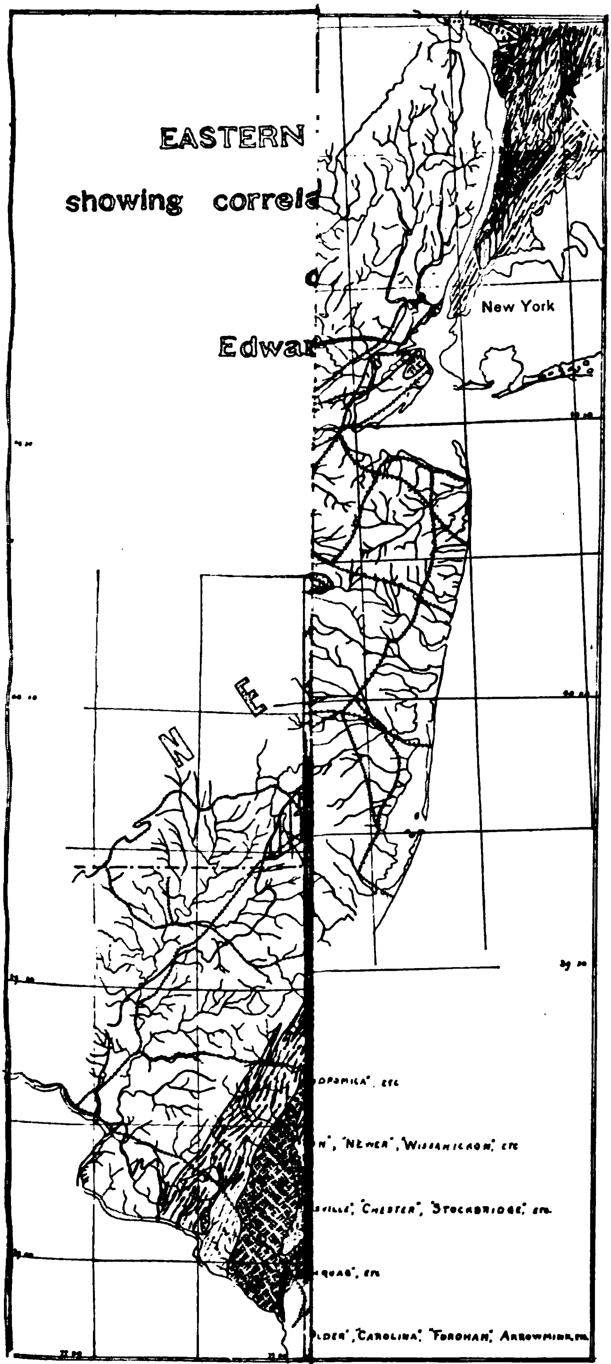


OSTEOPYGIS GIBBI Wieland.

Plastral view of type.—Entire length of specimen, 74.3 cm.

PROPLEURA BOREALIS, sp. nov. × 1/8.

N, Nuchal; 1, 2,—1st and 2d Neurals; Lm 1–3, 5, 6,—Left Marginals; M2, 3, 5–7,—Right Marginals; R. P. 1, 2, 4, 5,—Right Pleurals; L. P 1, 3,—Left Pleurals; H, Hyoplastron; Hp, Hypoplastron: X, X,—Xiphiplastra; L H, Left Humerus (dorsal view); P, Pubis; Il, Ilium; Is, Ischia.—Nuchal, and 1st and 2d vertebral horn shields, in ink outline.


EASTERN
showing correla
Edwa
New York
"Newer", "Wissahickon," etc
"Chester", "Stockbridge," etc.
"Carolina," "Fordham," Arrowmink, etc

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XIII.—*The Geology of the North End of the Taconic Range;* by T. Nelson Dale.* (With Plate XI.)

The Taconic range lies west of the Green Mountain range, and extends from near Fishkill on the Hudson, N.N.E., to a point two miles south of Brandon in Rutland County, Vt., where, geologically speaking, it ends. It consists mainly of schists of Ordovician (Hudson) age, but as its northern part is more or less merged in a hilly belt of Cambrian slate and quartzite, flanking it on the west and extending four miles beyond it, the range may be said, physiographically at least, to extend almost to the Addison-Rutland County line and thus to have a total length of 200 miles.

In the published geological maps the north end of this range has been variously represented: (1) As consisting of a narrow tongue of Cambrian slate extending as far north as Cornwall, bordered on both sides by the schist of the Taconic range, which extends only to Sudbury village on the west and to a point S.W. of Brandon village on the east.†

(2) Of similar constitution but cut off between Whiting and Sudbury by a narrow strip of limestone connecting the limestone of the Vermont Valley with that of Orwell.‡

(3) Of a simple belt of Cambrian shale, etc., extending as far north as Weybridge.§

*Published by permission of the Director of the U. S. Geological Survey.

† Hitchcock and Hager: Report of the Geology of Vermont, vol. ii, pl. i, 1861.

‡ Dana (James D.): An account of the discoveries in Vermont Geology of the Rev. Augustus Wing, this Journal, vol. xiii, 1877. Map opposite p. 334 but modified by explanations on pp. 336, 339, and embodied in another map in vol. xiv, p. 36, in paper by same author entitled: Supplement to the account of the discoveries in Vermont Geology of the Rev. Augustus Wing.

A copy of Mr. Wing's original MSS, kindly loaned to the author of the present paper by Prof. H. M. Seely of Middlebury, contains a sketch map showing the topographic details of this E.-W. strip of limestone.

§ Walcott (Charles D.): The Taconic System of Emmons, and the use of the name Taconic in Geologic nomenclature; this Journal, vol. xxxv, pl. iii, 1888.

The north end of the Taconic range is an important locality, for the principal formations of the Taconic region, the Cambrian slate etc., the Stockbridge Limestone of the valleys, and the Ordovician schists of the Taconic range, all meet there within an area of a few square miles. The topographic map of the Brandon quadrangle, recently finished by the U. S. Geological Survey, has at last made careful exploration of this key locality possible; and the results amply justify the opinion that careful geological mapping with a reliable topographic base is the only method of settling intricate geological problems, and that this mapping should cover large areas, not only to prevent the overlooking of such crucial localities but also to show the wideness of their significance.

The writer and his assistants, Messrs. Louis M. Prindle and Fred H. Moffit, were engaged from 1894 to 1896 in going over and extending Mr. Charles D. Walcott's reconnaissance work in the Slate belt of Washington County, N. Y., and Rutland County, Vt. The results were published in 1899 accompanied by a geological map extending from lat. 43° to 43° 45′, and covering a strip from 10 to 12 miles wide along the west side of the Taconic range, covering in all about 720 square miles.* The fact was there brought out by Mr. Walcott's paleontological data and corroborated by our stratigraphical observations,† that in that region along many miles of intricate geological boundaries, where faulting is out of the question, the Lower Cambrian slates, with their Olenellus fauna, occur in apparently conformable contact with the Ordovician slates, shales, etc., containing Hudson Graptolites. Similarly, the Ordovician schists of the Taconic range were found to be in contact on the west with Lower Cambrian slates along a stretch of 50 miles south of the township of Sudbury, and at only two points (Hubbardton) was there any marked divergence in the strike of the two formations. This involved the anomalous absence of the Stockbridge Limestone along the west foot of that range, whereas on the east side of it the upper part of this formation (of Chazy and Trenton age) dips everywhere conformably under the overlying schists of the Hudson.

During the summer of 1903, the north end of the Taconic range and the adjacent country were somewhat carefully, although not exhaustively, explored by the writer assisted by his son. The exposures were found to be sufficiently numerous to show the mutual relations of the several formations, and the results

* The Slate belt of Eastern New York and Western Vermont. by T. Nelson Dale, 19th Ann. Rept. U. S. Geol. Survey, 1889, Part III, pp. 153–307. Map, pl. xiii. Reviewed in this Journal, vol. clix, p. 382.

† See ibid., pl. xiii and pp. 290–295, on the relation of Cambrian and Ordovician.

are shown in the accompanying map and section, Plate XI.* The map shows a central tongue of Cambrian slate, quartzite, etc., bordered both on the east and west by narrow strips of Ordovician schist or slate, and, in its southern and eastern side, adjacent to a larger mass of Ordovician schist, two miles wide, which constitutes the north end of the Taconic range proper. This tongue of Cambrian is bordered on the north and at several points on the sides by the Stockbridge Limestone. The mass of Ordovician schists, shown at the upper edge of the map, which continues, with a possible interruption east of West Cornwall, 12 miles north to Middlebury and even beyond, is cut off, as was first shown by Wing, from the slate and schist on the south by the Stockbridge Limestone, and is not even indirectly connected, as one of his maps showed, with the Ordovician schists of the Taconic range. The Ordovician part of the Stockbridge Limestone, as shown by fossil localities, touches the Cambrian slates on three sides. The Cambrian part† of that formation, not indicated on the map, crops out near Brandon village, and extends north and east of it, forming a longitudinal belt between the Lower Cambrian quartzite (Vermont Formation) of the Green Mountain range on the east, and the Ordovician part of the Stockbridge Limestone on the west.

The determination of the age of the slates and schists of the north end of the Taconic range is based upon the following evidence: The Lower Cambrian age of the central slate mass in Sudbury is shown by the occurrence at intervals, as far north as the northern slope of Government Hill, a mile east of Sudbury Church, of a slightly ferruginous, calcareous, quartz sandstone, typical of that formation in Washington County, N. Y.;‡ by the fact that typical Lower Cambrian roofing slates are being quarried a half mile north of Stiles Mountain in Sudbury;§ by the presence of six localities of Lower Cambrian fossils in the same belt within two and one-half miles south of the southern edge of the area shown on the map; by the general petrographic charter (massive quartzite, quartzose slates, greenish and purplish roofing slates, calcareous sandstone) of a large part of the area designated as Cambrian. In places, however, petrographic distinctions fail, as the slates become schistose and resemble the Ordovician schist. The Ordovician age of the schist and slate masses bordering the Cambrian (Sh on map) is shown by the presence of red roofing slates, typical of the Hudson,‖ a mile S.S.E. of Hyde

* As to this map: those parts of the geological boundaries which are more or less uncertain are shown in dotted lines to distinguish them from those which are well established and indicated in full lines. The round black dot a half mile E.S.E. of Hyde Manor represents what seems to be an outlier of Ordovician limestone, about 70 × 40 ft. across, resting upon the Cambrian slates.

† Whether this Cambrian includes some Beekmantown is not yet determined.

‡ Horizon E of the slate belt. Op. cit. table facing p. 178.

§ Locality shown on map by crossed hammers.

‖ Horizon Irs of Slate belt. Op. cit. table facing p. 178.

Manor, and three-fifths of a mile E.S.E. of Sudbury Church, and again, apparently, in a badly weathered condition, one and one-fourth mile E.N.E. of Huff pond on the east side of the Cambrian belt; by the presence of typical schists of the Taconic range at the most northern summit of that range, three miles S.S.W. of Brandon village (elevation 1295 ft.); by indications of Ordovician fossils (Crinoid stems, etc.) in a small mass of included limestone, a mile N.N.W. of that hill;* and by the presence of graphitic sericite schist, so common at the base of that schist formation in Vermont and Massachusetts, in the small strip N.E. of Hincum pond. These age determinations are furthermore corroborated by a dominant, though not universal, N.E. strike in the Cambrian slates, and an almost equally prevalent N. or N.15W. or N.N.W. strike in the Ordovician schists and in the underlying limestone.

The structural relations of the formations are shown by symbols on the map and by the section above it, Plate XI. It will be noticed that the parallelism between the strike of the Cambrian and Ordovician, already referred to as characteristic of the slate belt to the south, still persists on the west side of the Cambrian slates near Horton and Burr ponds; but within a mile of Hyde Manor a marked divergence begins to appear, the Cambrian striking more or less N.E., the Ordovician N.15–25W.;† and this continues to the extreme N. end of the mass. The prevalent strike of all the rest of the Cambrian area is about N.E.; exceptionally, however, as east of Huff pond, possibly owing to a minor pitching fold or a small fault, a few N.W. strikes appear, and there may be others. The Ordovician schists of the east side of the Cambrian tongue are likewise marked by a N.15–25W. strike. This, indeed, is the trend and strike of the Taconic range as far south as West Rutland, eleven miles from the south edge of the map. A similar strike also appears in the limestone of the valley towards Brandon. But to this N.N.W. strike of the Ordovician there is also an exception, for the schists of the west side of the schist mass E. and N.E. of Stiles Mountain strike N.E. and a similar strike appears at several points in the limestone embayment east of the Cambrian. The cause of these N.E. strikes in the Ordovician is not apparent, unless it be a system of transverse folds like that occurring on the north end of Mount Anthony in Bennington. A mile N.E. of the Cambrian point the limestone resumes the normal strike of the Green Mountain region, and this recurs again at Leicester Junction, two miles north of the map. To all this should be added that the Cambrian slates have here and there a secondary cleavage foliation, striking N.15W., i. e. parallel to the strike of the bedding of the Ordovician schist.

* Locality marked F on map. † Exceptionally also N.—N.15E.

The section is drawn so as to cross contacts where the unconformity is manifest but owing to insufficiency of data, the folds represented in the Cambrian portion away from the contacts are largely hypothetical. The straightness of the Cambro-Ordovician boundary on the west side may be the result of faulting; but as the unconformity is quite as great at several points on the east side, where faulting is improbable, and as N.E. strikes are quite as characteristic of the center as of the sides of the Cambrian tongue, it is evident that faulting is not the cause of the unconformity. If it exists, it is between rocks which were already unconformable. Such a fault would have to be a reversed one and would hade to the east, bringing the Cambrian beds to overlie the Ordovician ones. The section has been constructed to show the relations without the faulting, although such faulting is regarded as quite possible. That the limestone once covered at least the western border of the Cambrian, is probable from the presence of the small outlier in the Hyde Manor Golf grounds, already referred to and shown in the section. This limestone strikes N.10E., as does also the nearest Ordovician limestone east of it, but the Cambrian slate about it strikes N.40E.

The interpretation of the facts set forth in the map and section is this: The Lower Cambrian slate formation, which is now regarded as the off-shore equivalent of the quartzite of the Green Mountain range (Vermont Formation of U. S. G. S. Monograph XXIII), was folded at the close of Lower Cambrian time and in places, raised above sea level, forming one or more islands in the Champlain oceanic arm. The direction of this Cambrian folding was generally the same as that of Ordovician time, known as the Green Mountain movement, but at this point the axes of these Cambrian folds, for some reason, had a more easterly course, resulting in N.E. strikes. A very gradual depression, beginning during the latter part of Stockbridge Limestone time and continuing into Hudson time, caused the deposition of some of the limestone and of all the schist upon these former islands of Lower Cambrian rocks. This, as suggested to the writer by Professor C. R. Van Hise, resulted in some places in an overlapping of the limestone by the Hudson schist and slate, and in others, in the deposition of the schist and slate immediately upon the Cambrian slates. This overlap, in particular, accounts for the absence of the Stockbridge Limestone for 50 miles along the west side of the Taconic range. In 1898* the writer sought to explain this by a local change from calcareous to argillaceous sedimentation during Stockbridge Limestone time, as had been proven by Pumpelly and

* Op. cit. Slate belt, etc., p. 295, last paragraph, to p. 297.

Wolff to have occurred on Hoosac Mountain.* That explanation of the relations about the Taconic range is now shown to be erroneous.

Then came the Ordovician folding which, here and as far south as West Rutland, produced N.15–25W. strikes, principally, and which may have produced the N.15W. secondary cleavage in the Cambrian slates, and must also have otherwise more or less modified the Cambrian structure as well as the Cambrian surface. The central part of the section shows the Cambrian folding, and the ends of it the overlapping and the Ordovician folding. Denudation through long geological periods must account for the presence of only shred-like remnants of the great mass of Ordovician argillaceous sediments and for the severance of the northern extension of the schist from the Taconic range, and, generally, for the exposure of the Stockbridge Limestone. The salient fact is the unconformity between the Lower Cambrian and the Ordovician, which is masked in the slate region of Washington Co., either by the parallelism in the strike of the two foldings or by the effect of the later one upon the earlier, but which was accentuated at the north end of the Taconic range by the original divergence in the strike of the two periods and is still shown in the dips. This unconformity thus fully corroborates, stratigraphically, the time break shown, paleontologically, by Mr. Walcott's fossil localities.†

Although the Taconic controversy was settled long ago, and has ceased to be of other than historical interest, as it was shown by Dana, Walcott and the authors of Monograph XXIII, that Ordovician rocks had been included by Ebenezer Emmons in his Taconic System owing to the overlooking of faults, the mistaking of cleavage for bedding and insufficient exploration of the areal relations, yet it is remarkable that at this late day it should appear that his contention that there was an extensive formation, marked by a peculiar fauna, now known as Lower Cambrian, unconformably related both to the underlying gneisses (pre-Cambrian) and to the overlying Lower Silurian rocks (Hudson, etc.), should be confirmed, at least for a part of the Taconic region, for no trace of the unconformity shown by this paper has yet been found along the Green Mountain border. During the Taconic controversy, however, conformable succession of the Cambrian and Ordovician beds was supposed by the opponents of Emmons to hold for the entire region.‡

* Geology of the Green Mountains in Massachusetts, by Raphael Pumpelly, J. E. Wolff, and T. Nelson Dale. Monograph, U. S. Geological Survey, XXIII, 1894, pp. 14–18, 104.

† Op. cit. Slate belt, pp. 163, 166.

‡ Rogers (Henry D.), this Journal (1), vol. xlvii, D., p. 152, 1844; Walcott (Charles D.), op. cit. this Journal, vol. xxxv, 1888, p. 320.

Pittsfield, Mass, December, 1903.

ART. XIV.—*Notes on some California Minerals*; by WALDEMAR T. SCHALLER.

HALLOYSITE.

THE pink clay occurring at Branchville, Ct., has been shown* to be montmorillonite, while that occurring at Norway, Me., has proven† to be cimolite. That from the lepidolite mine near Pala, San Diego Co., California, differs from both of the New England clays, being comparable with halloysite.

At Pala, the halloysite occurs in large seams, often several inches thick, and extending many feet in length. The clay is somewhat moist, but quickly dries to a crumbling mass when taken out of the mine. In color it is rather deeper pink than the Norway cimolite and occasionally is somewhat translucent. It readily crumbles to a fine powder when placed in water. The material analyzed had been drying in the air for over three months.

The results of analysis are:

SiO_2	43·62
Al_2O_3	35·55
Fe_2O_3	·21
MnO	·26
CaO	1·02
MgO	·19
Li_2O	·23
Na_2O	·19
K_2O	·03
H_2O (107°)	6·63
H_2O (ab. 107°)	12·25
TiO_2	none
	100·18

The iron was determined as Fe_2O_3, FeO not being tested for. The analysis agrees well with the formula

$$H_4Al_2Si_2O_9 + H_2O.$$

AMBLYGONITE.

The occurrence of amblygonite at the lepidolite mine at Pala, California, has already been noticed, and a somewhat fuller description of the mineral is here given. A large deposit has been uncovered and the indications seem to show that it is merely a small part of an extensive body of massive

* This Journal, xx, 283, 1880. † Ibid., xxxii, 355, 1886.

amblygonite. The mineral usually occurs pure; very rarely small amounts of lepidolite are present with it. Frequently broad cleavage faces with irregular outlines can be seen. The color is white and in thin pieces the mineral is translucent. It fuses easily, coloring the flame red, and in powder is difficultly decomposed by sulphuric acid.

An analysis of a specimen kindly presented by Mr. G. F. Kunz gave the writer the following results:

P_2O_5	48·83
Al_2O_3	33·70
Fe_2O_3	·12
MnO	·09
MgO	·31
Li_2O	9·88
Na_2O	·14
H_2O	5·95
F	2·29
TiO_2	none
	101·31
Less O	·96
	100·35

Regarding fluorine and hydroxyl as isomorphous, in the specimen analyzed the latter greatly predominates over the fluorine. The water was determined by igniting the mineral with lead oxide, previously heated nearly to fusion. Three determinations gave the loss of weight, due to the escape of water, as 5·89, 6·01, 5·95 per cent. The loss of the mineral on ignition was 8·03 per cent, equalling the sum of the water and fluorine content.

Boothite.

A specimen of a pale blue copper sulphate was collected at the copper mine near Campo Seco, Calaveras Co., California, by Mr. James Wise, and kindly presented to the writer for investigation. The pale blue color suggested that the mineral might be boothite instead of the more frequently occurring chalcanthite. The results of a chemical analysis have shown that the mineral is boothite, thus affording a second locality for this interesting mineral. Careful quantitative determinations of hydrous copper sulphates will probably show that the heptahydrate is not so rare as may be supposed.

The mineral from Campo Seco occurs massive, showing no crystalline structure. The average of several determinations afforded the following results:

			Ratio.	
CuO	26·13		1·00	
FeO	·81		·03	
MgO	·64		·05	
SO_3	27·25		1·04	
H_2O (110°)	36·76	41·67	6·22	7·06
H_2O (ab. 110°)	4·91		·84	
Insol.	3·96		....	
	100·46			

Formula, $CuSO_4.H_2O+6H_2O$.

A careful determination of the specific gravity of the mineral gave (21° C.) 1·944. This being much lower than the value obtained (2·1) on the boothite from Leona Heights, a redetermination of the latter was made on purer material collected since the publication of the first results.* This gave, as an average value, the figure (22° C.) 1·935. The average of these two determinations, or 1·94, is probably very near the true value for the specific gravity of boothite.

Pisanite.

A small specimen of massive pisanite from Gonzales, Monterey Co., California, was analyzed some time ago and the results are here presented. The quantity of material available for analysis was very small and the determinations do not claim any great accuracy. About 6 per cent of insoluble matter has been deducted and the results recalculated to 100 per cent.

		Ratio.	
CuO	7·56	·27	·89
FeO	15·85	·72	
SO_3	30·74	1·08	
H_2O	45·85	7·18	
	100·00		

The analysis approximates to the formula $CuO.2FeO.3SO_3.21H_2O$.

In the following table, all available analyses of pisanite are tabulated, and one can readily see that there is no definite ratio between the copper and iron. The formula is then written $(Cu,Fe)SO_4.7H_2O$, pisanite being an isomorphous mixture of melanterite and boothite. All the analyses are calculated to 100 per cent.†

* Minerals from Leona Heights, Alamada Co., California, by W. T. Schaller, Bull. Dept. Geol. Univ. of Cal., vol. iii, No. 7.

† Anal. No. 1, theoretical comp. of melanterite, $FeSO_4.7H_2O$; No. 2, Schaller, anal. quoted above; No. 3, Schaller, Bull. Dept. Geol. Univ. of Cal., vol. iii, No. 7; No. 4, Hintz, Zeit. Krys. ii, 309; No. 5, Hillebrand, Bull. U.S.G.S., No. 220, p. 105; No. 6, see No. 3; No. 7, Pisani, Comptes Rendus, 1859, xlviii, 807; No. 8, see No. 3: Nos. 9 and 10, Herz, Zeit. Krys. xxvi, 16; No. 11, theoretical comp. of boothite, $CuSO_4.7H_2O$.

No.	1	2	3	4	5	6
CuO	....	7·56	9·17	10·07	12·61	15·52
FeO	25·86	15·85	16·37	(16·15)	14·14	12·14
SO_3	28·80	30·74	29·00	28·84	28·44	27·82
H_2O	45·34	45·85	45·46	(44·94)	44·81	44·52
	100·00	100·00	100·00	100·00	100·00	100·00

No.	7	8	9	10	11
CuO	15·56	17·45	17·64	18·81	27·85
FeO	10·98	10·18	9·62	8·51	....
SO_3	29·90	28·43	28·27	27·93	28·02
H_2O	43·56	43·94	44·47	44·75	44·13
	100·00	100·00	100·00	100·00	100·00

Quartz Pseudomorph after Apophyllite.

At the Datolite and Pectolite* locality near Fort Point, San Francisco, Cal., a small group of crystals was found which were at first taken to be apophyllite. However, as the crystals proved to be infusible, a more extended investigation of the mineral was made.

The crystals, from one to three mm. in diameter, appear cubic with the corners truncated by small faces. Measurements of the best crystals showed that they are tetragonal and that they agree in angles with those of apophyllite. The forms present are the base, prism of the second order and the unit pyramid of the first order. The prism faces are vertically striated and faces of the other two forms are also rarely somewhat striated.

By trial it was found that hydrochloric acid does not attack the crystals, so the associated calcite was easily removed and pure material for analysis obtained. The crystals are opaque and no optical determinations could be made.

The analysis gave the following figures, showing that the crystals are now, chemically, essentially silica with various impurities.

SiO_2	90·58
Al_2O_3	1·58
CaO	1·87
MgO	2·20
H_2O	4·32
	100·55

* Mineralogical Notes by A. S. Eakle, Bull. Dept. Geol. Univ. Cal., vol. ii, No. 10.

Laboratory of the U. S. Geological Survey, November.

ART. XV. — *Crystallographical and Chemical Notes on Lawsonite;* by W. T. SCHALLER and W. F. HILLEBRAND.

CRYSTALS of lawsonite are very simple in their combinations, the common forms being the prism, base and brachydome. Two habits occur; tabular crystals with {001} and {110} and crystals with the forms {110} and {011}. The brachypinacoid and the brachydome {041} also occur. A large number of crystals from the typical locality in Marin County, California, were collected by the writer and carefully examined with a hand lens for any additional forms. Only two new forms were determined.

The forms observed on the six crystals measured are:

$c = 0 = 001$	$d = 01 = 011$
$b = 0\infty = 010$	$e = 04 = 041$
$m = \infty = 110$	$r = 2 = 221$
	$s = 3 = 331$

The angles measured, with those calculated for these forms, are quoted in the table following:

No.	Letter.	Symbol.		Measured.		Calculated.	
		Gdt.	Miller.	ϕ	ρ	ϕ	ρ
1	c	0	001	....	0° 02′	....	0° 00′
2	b	0∞	010	0° 00′	90 00	0° 00′	90 00
3	m	∞	110	56 22	"	56 22	"
4	d	01	011	0 09	36 36	0 00	36 27
5	e	04	041	0 00	71 18	"	71 18
6	r	2	221	56 27	69 10	56 22	69 27
7	s	3	331	56 22	76 21	"	75 58

The new pyramid $r = 2 = \{221\}$ is present on two crystals, the faces giving good reflections. Fig. 1 shows one crystal on which this form occurs.

The new pyramid $s = 3 = \{331\}$ is present on only one crystal and but one face of the form occurs. The relative size of the face is about the same as that of the preceding pyramid. The reflection was fair.

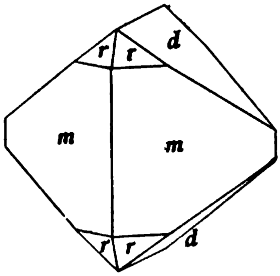
The brachydomes are usually deeply striated, rendering it difficult to determine with certainty any domes present. On two crystals, reflections were obtained from two faces, measurements of which agree with the angles calculated for the form {034}. The form is rather uncertain and is not included with the others.

Measured.		Calculated.	
ϕ	ρ	ϕ	ρ
0° 23′	28° 07′ —14′	0° 00′	28° 59′
0 00	28 07		

The combinations observed on the crystals measured are shown in the following table:

Cryst. No.	*c*	*b*	*m*	*d*	*e*	*r*	*s*
1	--	--	*m*	*d*	--	*r*	--
2	--	*b*	*m*	*d*	--	--	*s*
3	--	--	*m*	*d*	--	*r*	--
4	*c*	*b*	*m*	*d*	*e*	--	--
5	--	*b*	*m*	*d*	--	--	--
6	*c*	--	*m*	*d*	*e*	--	--

1



The following table is a calculation of the two new forms corresponding to the tables given in Goldschmidt's Winkeltabellen.

No.	Letter	Symbol	Miller	ϕ	ρ	ξ_0	η_0	ξ	η	x (Prism) ($x:y$)	y	$d = tg\,\rho$
6	*r*	2	221	56° 22′	69° 27′	65° 45′	55° 54′	51° 13′	31° 14′	2·2204	1·4770	2·6667
7	*s*	3	331	"	75 58	73 17	65 42	58 53	32 30	3·3306	2·2155	4·0001

Material carefully purified by the Thoulet solution followed by repeated electromagnetic extraction, and having then a specific gravity of 3·121 at 25°, gave the following results of analysis:*

* Concerning this purified material, Dr. Ransome reports as follows: "I should say the material is as pure as it is possible to get it. The grains are all lawsonite, but vary in individual purity. Some are perfectly clear. Others have minute inclusions, which appear in most cases to be solid particles but are too minute for identification. One of them, however, was suggestive of rutile. Some of the grains are slightly clouded with a yellowish stain which the microscope is unable to resolve into distinct particles. There are apparently a few fluid inclusions also."

		Mol. Ratio	Calc. for the formula $H_4CaAl_2Si_2O_{10}$
SiO_2	38·45	1·98	38·34
TiO_2	0·38		
Al_2O_3	31·35	0·97	32·44
Fe_2O_3	0·86		
FeO	0·10	1·00	17·80
MnO	faint trace		
CaO	17·52		
MgO	0·17		
K_2O	0·23		
Na_2O	0·06		
H_2O (ignition)	11·21	1·95	11·42
	100·33		100·00

Titanium is not considered in the ratio because probably present as an inclusion of rutile or titanite. If the latter, the ratio would perhaps approximate still more closely to the theoretical than it does. The agreement with the formula deduced by Ransome and Palache from their rather widely differing analyses is very satisfactory. The behavior of the mineral before the blowpipe is somewhat different from that given by those authors, or rather their statement needs amplification. On first applying the flame, a splinter appears to fuse easily as stated, and there is formed a blebby glass, or on larger splinters a porous sinter, but this fusing is only momentary, and it requires the highest heat attainable, under which the fragment emits quite an intense light, to produce a further softening and rounding of the edges. If a rather large splinter is held in the flame of the blowpipe, or in a small flame of a blast lamp, a very sudden and marked exfoliation is observed, but even the extruded points and edges do not fuse completely in the highest attainable heat. The semi-fused surface, however, appears on cooling dark and sometimes nearly black where the heat was most intense. If care is taken, in producing this exfoliation, to apply the flame but for a moment, it has been noticed that a singularly shaped excrescence may shoot out from a point of the surface.

Laboratory of the U. S. Geological Survey, November.

Art. XVI.—*A Determination of Nitrites in Absence of Air*; by I. K. Phelps.

[Contributions from the Kent Chemical Laboratory of Yale University—CXXIV.]

Dunsten and Dymond* have recommended the use of an evacuated flask for the estimation of nitrites by the action of potassium iodide in acid solution. Under these conditions, the nitrous and hydriodic acids interact to produce nitric oxide (which must be kept from contact with gaseous oxygen) and iodine which is determined by decinormal sodium thiosulphate. As objections to the process may be cited the necessity of getting an absolutely gas-tight, rubber-jointed apparatus and the restriction put upon the size of the flask by the two considerations of withstanding the atmospheric pressure when evacuated and yet being thin-walled enough to allow of the ready heating of the flask. A practical test of a slight modification of the device already used in the determination of nitric acid† for getting an inert atmosphere proves to obviate these difficulties and to leave little to be desired in point of accuracy.

The apparatus used was the same as in the estimation of nitric acid already referred to above. It consisted of a boiling flask of 250^{cm^3} capacity closed with a rubber stopper carrying in its two perforations the inlet and exit tubes. A stoppered funnel of 50^{cm^3} capacity with its tube constricted at its lower end was used as an inlet tube; and a glass tube of $\cdot 8^{cm}$ internal diameter, enlarged just above the stopper to a small bulb (to prevent mechanical loss of the solid contents of the flask during the boiling) and bent twice at right angles, served as an exit tube. The flask was supported in the usual manner at a convenient height to allow of heating with a Bunsen burner placed beneath and the exit tube was made of a sufficient length to reach to the surface of some mercury contained in a test tube to the depth of about three centimeters.

The analysis was made as follows: An amount of standard arsenious acid solution, slightly in excess of that required to take up the iodine to be set free later by the nitrous acid, and 25^{cm^3} of a concentrated solution of sodium carbonate were placed in the flask. The stem of the dropping funnel was completely filled with water, the rubber stopper inserted tightly, and the contents of the flask boiled until all air was expelled—a process requiring an active boiling of 5–8 minutes. The flame was then removed, the exit tube plunged deep into the mercury by changing the position of the flask on its wire gauze—which is particularly easy if the gauze is well depressed at

* Pharm. Jour. [3], 19, 741.

† This Journal, xiv, 440 (1902).

the center and the flask placed well up on the higher part in the preceding operation—and sulphuric acid (1–4) sucked in through the funnel tube as the flask cooled, the cooling to the room temperature being hastened by standing the flask in a dish containing ice and water. In all, 7^{cm^3} of sulphuric acid were added, this amount having been found by previous experiment to be nearly but not quite enough to neutralize the sodium carbonate used and also having been found to yield a little more carbon dioxide than the apparatus can hold at the atmospheric pressure. As soon as the diminished pressure in the apparatus was too weak to suck in the acid, the position of the flask was again changed on the wire gauze so that the exit tube was raised out of the mercury into the layer of water which had condensed during the preceding boiling and which then served to trap the apparatus from the outside air. After the acid had been added and had been washed in carefully, the nitrite solution to be analyzed containing 2 grms. of pure potassium iodine was introduced into the flask through the funnel and this was followed by sulphuric acid (1–4) in sufficient amount (5^{cm^3}) to render the contents of the flask acid in reaction. Potassium bicarbonate was then added in concentrated solution to alkaline reaction or until the free iodine had been taken up, the mixture boiled for about five minutes to expel the nitrogen dioxide, cooled, and titrated to color with decinormal iodine in the presence of starch paste. In making the various additions of liquid to the flask, care was necessarily taken that no air was introduced with the liquid. Table I records experiments made in this manner upon a solution of commercial sodium nitrite, standardized by treatment with potassium permanganate and oxalic acid in acid solution according to the procedure of Kinnicut and Nef.*

TABLE I.

	$NaNO_2$ taken. grm.	Oxygen value of As_2O_3 taken. grm.	Oxygen value of As_2O_3 found. grm.	Error on Oxygen. grm.	Error on $NaNO_2$. grm.
1	0·0958	0·01200	0·00064	0·00025 +	0·0011 +
2	0·0958	0·01200	0·00066	0·00024 +	0·0010 +
3	0·1916	0·03200	0·00965	0·00017 +	0·0007 +
4	0·1916	0·03200	0·00965	0·00017 +	0·0007 +
5	0·3832	0·05600	0·01120	0·00043 +	0·0018 +
6	0·3832	0·05600	0·01118	0·00045 +	0·0019 +
7	0·6716	0·08000	0·00160	0·00076 +	0·0033 +
8	0·6716	0·08000	0·00158	0·00078 +	0·0034 +
9	0·1916	0·03280	0·01003	0·00062 +	0·0027 +

* Amer. Chem. Jour., v, 388 (1883).

The experiment numbered 9 is included to show a fact found early in the investigation, namely, the necessity of boiling out the nitrogen dioxide before titrating the residual arsenious acid. It was made like 3 and 4 above up to that point, when in stead of boiling out the nitrogen dioxide, cooling, and titrating, it was treated with a slow stream of air bubbling through for fifteen minutes and then titrated. Evidently the nitrogen dioxide in oxidizing affects the arsenious acid slightly.

When the sulphuric acid is being added to the alkaline solution containing the arsenite, iodide, and nitrite, iodine is set free locally but is at once taken up by the alkaline arsenite, so that finally, when the acid reaction is reached, there is only a small amount of it free, no matter how much nitrite may have been used. This condition reduces to a minimum the possibility of a loss of iodine by volatilization.

As might be anticipated, the two processes show slightly different results, the process outlined above tending to give results in excess of the theory on account of the action of dissolved oxygen, while that of Kinnicut and Nef should show a deficiency as compared with theory, since the loss of nitrogen oxides is evidenced by the odor when even a very dilute solution of a nitrite is acidified.

ART. XVII.—*The Use of Ferrous Sulphate in the Estimation of Chlorates and Bromates;* by I. K. PHELPS.

[Contributions from the Kent Chemical Laboratory of Yale University—CXXV.]

IN a recent article,* a method for the titrimetric estimation of nitric acid or nitrates was described. It consisted, briefly, in the measurement of the amount of ferrous salt oxidized in the reduction of the nitric acid to nitric oxide by an excess of ferrous sulphate in the presence of hydrochloric acid. The value of ferrous sulphate as a reducing agent in analytical processes has been long recognized on account of its ready availability, the high degree of precision with which it may be determined, and the extreme slowness with which it is oxidized by atmospheric oxygen. This last fact was clearly shown by Peters and Moody† for solutions which had been allowed to stand until all active oxygen, dissolved in the water, or otherwise present, had produced its effect. The author was surprised to find that, in boiling such solutions in the open air and cooling with stirring in running water, no distinctly perceptible change could be noted, although the oxidation from day to day was plainly evident.

Carot‡ has suggested the use of ferrous sulphate for determining the oxygen in hypochlorites and chlorates in admixture with chlorides but gives no evidence to show the degree of accuracy of the process. Table I records experiments made with the purest potassium chlorate of commerce to test this point. The dry salt was weighed out, treated with an excess of standardized ferrous sulphate solution $\left(\text{approximately } \frac{n}{5}\right)$, and with 15^{cm^3} of sulphuric acid (1 : 4). This mixture was brought to the boiling point in a trapped flask, cooled to room temperature by immersion in running water, diluted to a volume of 600^{cm^3}, and, after the addition of 1–2 grms. of manganous chloride, titrated to color with standard potassium permanganate solution.

TABLE I.

$KClO_3$ taken. grm.	Oxygen value of ferrous salt taken. grm.	Oxygen value of ferrous salt found. grm.	Error on $KClO_3$. grm.
0·0500	0·02756	0·00814	0·0004 −
0·0500	0·02739	0·00781	0·0000 ±
0·1000	0·04934	0·01024	0·0002 −
0·1000	0·04951	0·01043	0·0002 −
0·2000	0·09086	0·01247	0·0002 +
0·2000	0·09078	0·01277	0·0008 −
0·5000	0·20552	0·00993	0·0006 −
0·5000	0·20543	0·00980	0·0005 −

* This Journal, xiv, 440 (1902). † This Journal, xii, 369 (1901).
‡ Compt. Rend., cxxii, 449.

Table II records similarly experiments made upon a sample of thrice crystallized potassium bromate which was prepared by acting on potassium hydroxide with bromine evolved from pure potassium bromide by sulphuric acid and manganese dioxide. The experiments were performed like those with the chlorate, described above, except that the excess of ferrous salt used in the reduction was determined by decinormal iodine in alkaline solution instead of by permanganate in acid solution. The solution was cooled after boiling, was nearly neutralized with a concentrated solution of sodium carbonate, and was then treated with 2–3 grms. of Rochelle salt in solution and an excess of decinormal iodine solution. The mixture was made alkaline with an excess of potassium bicarbonate solution, starch paste added, the starch blue bleached with decinormal arsenious acid, and, finally, the excess of this last titrated to color with iodine.

TABLE II.

$KBrO_3$ taken. grm.	Oxygen value of ferrous salt taken. grm.	Oxygen value of ferrous salt found. grm.	Error on $KBrO_3$. grm.
0·0500	0·01776	0·00357	0·0006 —
0·0500	0 01770	0·00336	0·0001 —
0·1000	0·03792	0·00942	0·0008 —
0·1000	0·03792	0·00922	0·0001 —
0·2000	0·06321	0·00576	0·0000 ±
0·2000	0·06321	0·00580	0·0002 —
0·5000	0·15670	0·01342	0·0013 —
0·5000	0·16212	0·01870	0·0008 —

An inspection of the results shows that the processes may be justly considered as accurate for analytical purposes—especially so when one considers that they measure only the oxygen in the salt analyzed, which is 39 per cent for potassium chlorate and 28 per cent for potassium bromate.

ART. XVIII.—*Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. WORTMAN.

[Continued from vol. xvii, p. 140.]

On the Affinities of the Omomyinæ.

As I have already fully stated, my arrangement of this group of Primates under the Paleopithecine division of the Anthropoidea is only provisional. The incompleteness and frag-

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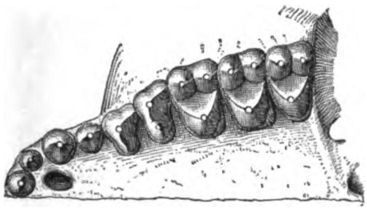


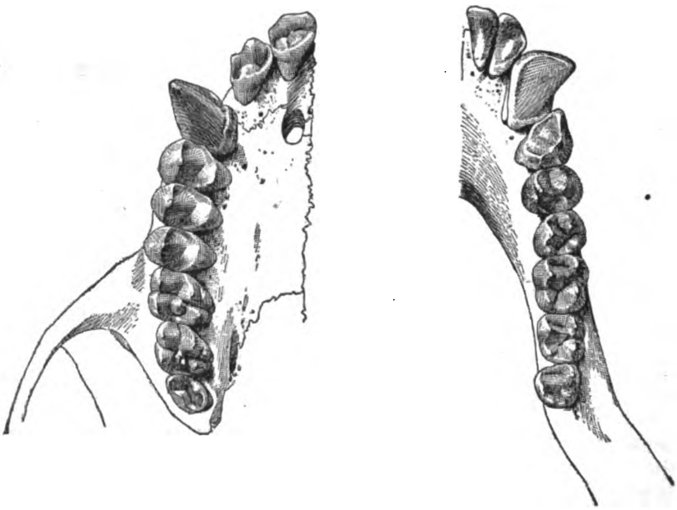
FIGURE 135.—Lower jaw of *Tarsius spectrum;* crown view; two and one-half times natural size.

FIGURE 136.—Upper teeth of *Tarsius spectrum;* crown view; two and one-half times natural size.

mentary condition of the remains of all the species thus far known precludes the possibility of determining their affinities and position with any great degree of exactness. It has been pointed out that the dentition of the lower jaw, and presumably that of the upper jaw also, in all the species in which it is definitely known, is represented by two incisors, a canine, three premolars, and three molars. This number differs from that of *Tarsius*, figure 135, in the presence of an additional incisor, there being only a single pair in the lower jaw of that genus. The structure of the lower molars and premolars accords well, moreover, with that of *Tarsius*, which undoubtedly represents a very generalized pattern among the Primates, and one from which it is possible to derive all the more complex types of the higher forms. In the structure of the superior molars, all the species of the Omomyinæ have apparently advanced beyond

the *Tarsius* stage, figure 136. This is seen in the continuation of the cingulum forward, around the internal face of the crown, and the development of a distinct cingular cuspule internal to the main antero-internal cusp. In the two external roots of the fourth superior premolars, however, the species of the Omomyinæ, as far as known, agree with *Tarsius*. This is very probably a generalized character, also, since there is very strong presumptive evidence that the single external root of the third and fourth premolars, common in the higher apes, is the result of degeneration caused by the shortening of the face.*

137 138



FIGURES 137, 138.—Upper and lower teeth of *Cebus apella;* crown view; three halves natural size.

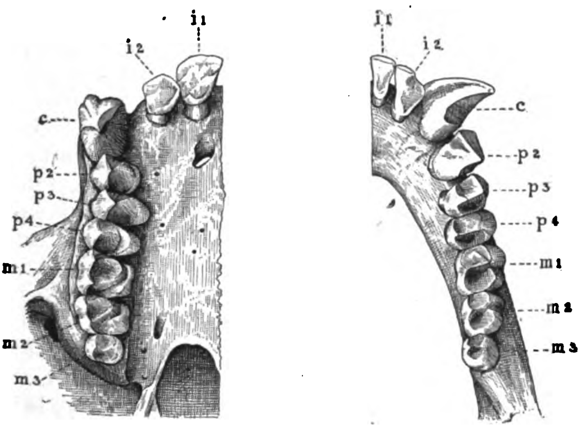
The final determination of the exact relations of these forms to *Tarsius* must await the discovery of the lachrymal region, as well as of the structure of the limbs and feet.

It is proper, however, to call attention in this connection to some striking resemblances which this group exhibits to certain of the South American apes, notably the capuchins and squirrel monkeys. In the former of these, of which *Cebus apella*, figures 137 and 138, is a good example, the upper molars present a characteristic and in many respects a peculiar and distinctive pattern. The first molar is the largest of the series

* In *Cebus* the external root of the third and fourth premolars is either deeply grooved or completely divided at the end. This is likewise true of *Mycetes*, as well as of many species of Old World apes. An example of the fusion of the external roots is seen in the last molar of many species of apes where it is strongly reduced, as in *Cebus*, *Chrysothrix*, and others.

and the last is the smallest, being considerably reduced. In the crowns of the first and second, the trigonal ridges are distinct, and there is a prominent intermediate cusp present. The postero-internal cusp is well developed and has a position much more internal to the antero-internal than is generally the case in molars of the higher Primates. Because of its position this cusp is more widely separated than usual from, and does not develop a close connection with, the original trigon. There is a strong cingulum continued forward around the inner face of the crown, from which a small cingular cuspule is formed internal to the main antero-internal cusp. This is most dis-

139 140



Figures 139, 140.—Upper and lower teeth of *Chrysothrix sciurea;* crown views; twice natural size.

tinct in the second molar, although a considerable rudiment of it is seen in the first. In the squirrel monkey, *Chrysothrix sciurea*, figures 139, 140, and 141, the superior molars exhibit practically the same structure as those of *Cebus*, the only important difference between the two being that the posterior intermediate cusp is not distinct in *Chrysothrix*. The cingulum is continued around the inner face of the crown in both the first and second molars in the same way as it is in *Cebus;* but its development is greater in the first molar than in the second, whereas in *Cebus* the cingulum and the anterior cingular cusp are stronger in the second than in the first.

This peculiarity in the structure of the molars is not found in any other South American ape, nor, as far as I am aware, in any other living species of Primate in any part of the world. It is highly significant, therefore, that so unusual a modification and one so entirely unique among the Primates should be

met with in its incipient stages in the typical North American Eocene group Omomyinæ. As we have just seen, this character is found in the upper molars of all the species, and may be said to be especially characteristic of them. We know, moreover, that they are Primates; that the dental formula for the lower jaw and presumably for the upper is the same as in the Cebidæ; that the number, structure, and relations of all the teeth of certain species, at least, so completely fulfil the requirements and conditions which one would naturally seek in an ancestor of these living Cebidæ, as to make it scarcely possible to believe that such striking resemblances can be altogether accidental. In fact, this is the only group of Primates that has ever been found, among either living or extinct forms outside of South America, which exhibits any approximation to any of the Cebidæ, and until some tangible evidence to the

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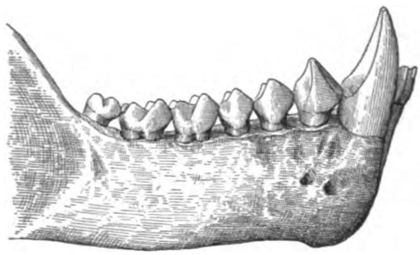

Figure 141.—Lower jaw of *Chrysothrix sciurea*; side view; twice natural size.

contrary is forthcoming we are compelled to regard these extinct North American types as the source from which the ape fauna of the Neotropical realm had its origin.

It has been assumed by some who have sought to solve the problem of the origin of the Cebidæ, that they were derived from Africa, and making their way thence across an Antarctic land connection, thus reached South America. This view is based upon the presence in the Patagonian Miocene of the remains of numerous Marsupials closely allied to those now living in Australia, which argues strongly for a land connection with that continent during the Tertiary. From resemblances among certain living species from South America to those of Africa, as well as among some of the extinct forms, it is further assumed that this land bridge extended to Africa, and that there was an interchange of species between the two Hemispheres. While this may perhaps satisfactorily account for the presence of those African types in South America, it does not

apply to its simian population. The insuperable objection to an African origin for the Cebidæ is found in the complete absence of any group of Primates, either fossil or recent, in the tropics or any part of the Eastern Hemisphere, which exhibits any near affinities with the New World apes. Africa is to-day the congenial home of a large and varied lemuroid and simian population in which species of the highest and lowest degree exist side by side. Something is known, moreover, of the ancient representatives of this Primate fauna from the Tertiaries of Europe and Asia, but whether we consider the living or extinct forms, not a single species has yet been brought to light among them which does not proclaim its distinctive relationship and bear the unmistakable stamp of its affinities with the Primates of the Old World. Among the monkeys and apes, this is so positive that no one has ever ventured to assert the contrary.

In like manner, the fossil monkeys of South America exhibit the closest relations to those species now living there. Ameghino has found the remains of apes in the Santa Cruz Miocene of Patagonia, which are closely allied to, and hardly distinguishable from, the living *Cebus* of the Amazonian tropics. They exhibit no traces of relationship with any species inhabiting Africa. Any direct connection between the Cercopithecidæ and the Cebidæ may be dismissed, therefore, as utterly untenable and unsupported by a single fragment or vestige of evidence. Neither can it be logically argued that the Cebidæ, originating in Africa, migrated thence in a body to the New World. No assignable reason can be given why all the genera, species, and individuals of so large and varied an assemblage as the New World apes must have been, even prior to the Miocene, should have suddenly quitted the home of their birth, without leaving behind a single representative or trace which would furnish a clue to their former presence in a region now so well fitted, apparently, for ape existence. Any such vestige, however, is singularly absent, and from whatever point of view we choose to regard it, such a hypothesis appears simply impossible.

In connection with the evidence which I have already brought forward in favor of the North American origin of the Edentata,* a similar origin for the South American Primates, which is the only alternative hypothesis conceivable, is placed upon an extremely probable, if not absolutely secure, foundation, and is entitled to infinitely greater consideration than any purely conjectural origin of these forms, wholly without evidence in its support. I have formerly suggested that the so-called Litopterna were direct derivatives of *Meniscotherium* of our Wasatch

* The Ganodonta and their Relationship to the Edentata, Bull. Amer. Mus. Nat. Hist., vol. ix, pp. 59–110, 1897.

beds, and I now further venture to believe that all the South American Ungulates, including the Toxodonts, Typotheres, Astrapotheres, etc., are but modified descendants of our North American Condylarths, and were derived from the same region as the Edentates and Primates.

Subfamily Anaptomorphinæ.

As already indicated, the genera of this subfamily agree in having only eight teeth in the lower jaw. It is in all probability not a natural assemblage, since it is tolerably clear that the missing teeth are not the same in the various genera. Until this is more fully determined by better specimens, the present classification must be regarded as by no means final. The genera composing this group can be distinguished by the following characters:

Lower molars having four cusps on trigon, all distinct; heel of last molar with four cusps; first and second molars not especially wider behind than in front; last molar largest of the series; fourth lower premolar with moderately strong internal cusp and rudimental heel; third premolar with very small rudiment of internal cusp; canine larger than second premolar or incisor; only one pair of incisors in lower jaw (?); superior molars tritubercular, with more or less rectangular outline; intermediate cusps small, but distinct; postero-internal cusp well developed on crown of first and second molars, but not distinct on third.
Washakius.

Lower molars having only two cusps on trigon; last molar unknown in type; first and second molars widening rapidly behind; third and fourth lower premolars without internal cusps; canine larger than incisors; second premolar absent in type; two pairs of incisors in lower jaw; upper teeth unknown in type.
Anaptomorphus.

Lower molars having only two cusps on trigon, a vestigial anterior cusp on first; heel of last molar with three cusps; first and second molars wider behind than in front; last molar not reduced; fourth lower premolar with well-developed internal cusp; second tooth of the series vestigial and implanted external to the tooth line; superior molars quadritubercular.
Necrolemur.

Washakius insignis Leidy.

Washakius insignis Leidy, Contr. Ext. Fauna West. Terr., 1873, p. 123.

Leidy's type of this genus and species consists of a fragment of a lower jaw carrying the second and third molars so much worn as not to display the arrangement of the cusps. Up to the present, this specimen has remained the sole example of the species, which on account of its imperfect representation

has had no very definite standing. Its relationship to the Primates, even, has been called in question, and it has been thought by some to belong to the Rodentia. There are, however, about ten individuals represented in the Marsh collection, which I do not hesitate to refer to Leidy's genus and species. The most conclusive point in this identification is found in the extra cusp on the inner posterior surface of the trigon of the lower molars, the remains of which can be still plainly seen in the much-worn molars of Leidy's type. In one specimen in the Marsh collection, there is in association with the lower teeth a fragment of an upper jaw containing two molars, so that the structure of the teeth can be made out with a reasonable degree of accuracy.

The complete dental formula of the lower jaw is not known with absolute certainty, but in one specimen the front of the jaw is sufficiently preserved to render it highly probable that there was but a single pair of incisors. At all events, if the

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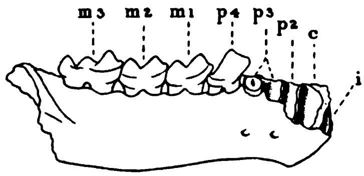

Figure 142.—Right lower jaw of *Washakius insignis* Leidy; side view; two and one-half times natural size; drawn from two specimens.

middle incisors were present they must have been exceedingly small. A good idea of the relations of the lower teeth can be had from the accompanying illustration, figure 142, which was drawn from two specimens. The outer side of the front of the jaw is injured so that the lower part only of the alveolus for the incisor is shown; this is seen to be smaller than that for the canine. Following this without diastema is a small alveolus for the second premolar, after which come the double-rooted third and fourth premolars. The crown of the second, figure 143, has a simple pointed summit, to which is added a small anterior basal, and a stronger internal cusp. That of the second has a similar structure but the internal cusp is better developed. In both the third and fourth premolars, the internal cusp is placed rather low upon the crown. The heel is rudimental.

The molars are peculiar in the composition of their crowns, by reason of the possession of an extra cusp situated internal and a little posterior to the main antero-internal cusp. The trigon thus has four cusps, a condition unknown in any other species of Primate. The remaining cusps of the trigon are

normal in their relations to the crown, the anterior one being distinct in all the molars. The heel of the first and second molars has the usual two cusps and is but little wider than the anterior portion or trigon. In the last molar, however, the heel has four cusps, which is again a unique character among

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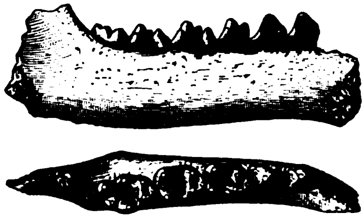

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FIGURE 143.—Left lower jaw of *Washakius insignis* Leidy; inside and crown views; two and one-half times natural size; drawn from two specimens.

FIGURE 144.—Last left lower molar of *Washakius insignis* Leidy; crown view; five times natural size.

the Primates. An outline view of the grinding surface of the crown of the last lower molar of the left side, enlarged five times, is given in figure 144, which represents accurately the arrangement of the cusps. The enamel of the crowns of all

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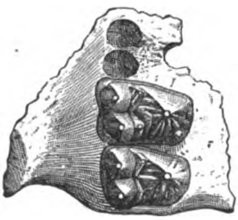

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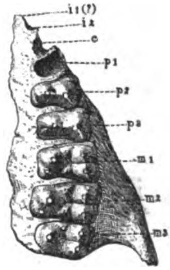


FIGURE 145.—Last two superior molars of the right side of *Washakius insignis* Leidy; crown view; four times natural size.

The postero-internal cusp of the second molar is not represented strong enough in the drawing.

FIGURE 146.—Left superior maxillary of *Washakius insignis* Leidy; crown view; two and one-half times natural size.

the lower teeth is strongly wrinkled, that occupying the valley of the heel especially so.

The fragment of upper jaw associated with the lower teeth, figure 145, contains the second and third molars. The second molar is larger than the third, although the disparity in size is not so great as in *Omomys* or *Hemiacodon*. The crowns are

tritubercular, with only a moderate development of the postero-internal cusp, and the cingulum is not continued forward around the internal face of the crown and does not develop the internal cingular cuspule seen in *Omomys* and *Hemiacodon*. The outer cusps are slightly flattened externally, and the intermediates are moderately developed. The enamel is much wrinkled, particularly that upon the inner portion of the crown. A second specimen, representing upper teeth, consists of a large part of the superior maxilla containing all the molars and the third and fourth premolars, figure 146. It also exhibits the alveoli of the second premolar, canine, and probably two incisors; that of the first incisor is, however, very indistinct, and one can not be sure that it was actually present.* In this specimen the second molar is larger than either the first or third, which are subequal. The postero-internal cusp is more distinct in the first molar than in the second or third. The premolars display single external and internal cusps, with a strong postero-internal cingulum tending to the formation of an additional cusp. The canine, as indicated by the size of the alveolus, is larger than the outer incisor or second premolar, and, as in the lower jaw, the teeth were implanted in a continuous row. The infraorbital foramen is single and issues above the anterior border of the third premolar in the same relative position as in *Hemiacodon*. The malar did not reach the lachrymal, thus leaving the maxillary a large share in the anterior boundary of the orbit, which was enlarged.

From these many resemblances to the Primates, there can not apparently be any question of the affinities of the genus, notwithstanding the peculiarities of the structure of the lower molars. It seems to have left no modified descendants, however, in the existing fauna.

Anaptomorphus æmulus Cope.

Anaptomorphus æmulus Cope, Proc. Amer. Philos. Soc., October, 1872 p. 554.

This genus and species were proposed by Cope upon the greater portion of a left mandibular ramus now preserved in the American Museum collection, which, as far as I am aware, is the only specimen of this species known. The jaw carries the first and second molars and the fourth premolar, together with the alveoli for all the remaining teeth, eight in all. The formula has been generally considered to be two incisors, a

* That which leads me to suspect the presence of two incisors in the upper series is the sharp inward curvature of the lower jaw near the symphysis, giving a greater transverse width in this region of the mouth. There would thus be a considerable gap left between the outer incisors and the median line. I think there can be little doubt that this space was occupied by a central pair of incisors.

canine, two premolars, and three molars, principally for the reason that the alveolus for the third tooth is enlarged after the manner of a canine, while the two in advance of it are small and hence have been thought to represent incisors. This determination is very probably correct, but it can not be accepted as final until the upper teeth are fully known. The extreme reduction in the number of premolars is a condition more advanced than that found in any other species of Primate, either living or extinct, in the Western Hemisphere; and that it should have taken place as early as the Eocene is indeed remarkable. In agreement with this reduction, it may be noted, however, that the structure of the lower molars is further advanced than that of any of its contemporaries in the Bridger. This is seen in the loss of the anterior cusp of the trigon from all the molars, and their consequent reduction to the four-cusped stage. I have already called attention to certain resemblances in the structure of the molars between *Anaptomorphus* and *Euryacodon*, but the former exhibits a greater advance in the modification of these teeth.

A second species, *A. homunculus*, was described by Cope from the now famous cranium found by me in the Basin of the Big Horn, in 1881. This cranium, together with a second specimen (No. 41 of the American Museum collection) which I also discovered in 1891, in the same region, has recently been refigured by Osborn.* These drawings are beautifully executed, but it is to be regretted that the skull is represented as complete in front, which is by no means the case. Osborn's figure gives the impression that the face is as much shortened and as reduced as in the highest type of living ape. Cope's original figure, in his Tertiary Vertebrata, is far more accurate in that it represents the entire anterior portion of the skull as missing. After a most careful study of the remains of this species in the American Museum collection, I find myself unable to agree with Cope in regard to the dentition of the cranium in question, or with Osborn concerning the dentition of the additional specimens. Cope determined the premolar dentition of the upper jaw to be two, and Osborn gives the number of lower premolars as three. The facts may be briefly stated as follows: In the cranium, there is evidence of the presence of seven teeth; of these, three are undoubtedly molars, and the remainder incisors, canine, and premolars; the most anterior tooth indicated is represented by an alveolus; the next is a pointed single-rooted tooth separated by a short diastema from those behind; the two following teeth are undoubtedly premolars, with single external and internal cusps.

* American Eocene Primates, Bull. Amer. Mus. Nat. Hist., 1902, p. 200.

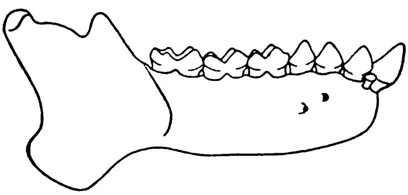
The element of uncertainty comes in the determination of the nature of the first two teeth, and I can find no proof that the single pointed tooth is the canine, as held by Cope and Osborn. There is certainly no indication of the maxillo-premaxillary suture to be found, and the tooth in question may quite as well be a premolar as a canine. In fact, in the fragmentary maxilla of the other specimen (No. 41) there is evidence of a tooth with more than a single root in advance of the two premolars, and if the two specimens belong to the same species, which is more than likely, there were certainly three premolars in the upper jaw. In like manner I am unable to discover any conclusive evidence in favor of Osborn's statement that there are three premolars in the lower jaw, together with a canine and two incisors. I am strongly inclined to believe that there were three premolars in the lower jaw, however, and that Osborn's determination is correct; but at the same time the specimens are not sufficiently perfect to furnish conclusive proof of the fact. Nor can it be demonstrated at the present time that the Big Horn and the Bridger species belong to the same genus. Upon general considerations, I think it most unlikely. I believe, moreover, that the Big Horn species is a type with three premolars above and below, and that it is generically distinct from the Bridger *Anaptomorphus.* I have refrained from proposing a new genus for this species, preferring to let the matter rest until the dentition of both the Big Horn and the Bridger forms is more fully known.

In the matter of the restoration of the skull, I can find no warrant for the extremely abbreviated face which Osborn gives in his drawing. The contour of the muzzle was undoubtedly much more like that of *Tarsius*, with which the cranial anatomy so closely agrees. Apparently very little consideration has been given to these resemblances between *Tarsius* and the Big Horn fossil, which Cope pointed out. It will perhaps be well to recall them here, with some emendations and additions. They are as follows: (1) The species are of about the same size, both being small; (2) the brain development is relatively large; (3) the brain projects well backward beyond the foramen magnum, so as to overhang the occiput; (4) there is no sagittal crest; (5) the face is considerably shortened, and the orbits are large; (6) the canal for the internal carotid pierces the petro-tympanic; (7) the dentition is very probably the same, with the exception of the loss of one pair of incisors in the lower jaw in *Tarsius;* (8) the structure of the molars and premolars is very similar; (9) the bullæ are much inflated, and the external wings of the pterygoids extend backward, so as partially to enclose the bullæ externally; (10) the lachrymal extends out upon the face, and the opening of the lachrymal

canal is external to the orbit; (11) although not positively known, the relations of the lachrymal and malar are the same.

There are some differences to be noted, but they relate entirely to the assumption of modernized features on the part of *Tarsius*. Upon the whole, the resemblances are so striking and strongly marked that apparently there can not be the slightest question, not only of the close relationship between the two forms, but of the further important fact of their common origin. I have already suggested that the place of this origin was within an ancient circumpolar land.

147



148

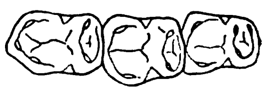


FIGURE 147.—Right lower jaw of *Necrolemur Edwardsi* Filhol; enlarged several times. (After Filhol.)

FIGURE 148.—Three lower molars of *Necrolemur Edwardsi* Filhol; crown view; enlarged. (After Filhol.)

Necrolemur may or may not belong in this series. If it does, it is by no means as closely allied to *Tarsius* as the American species. It has been suggested by Leche that it is related to the Indrisine lemurs, and there is indeed much in favor of such a view. If one compares the lower jaw of *Necrolemur Edwardsi*, figure 147, with that of *Propithecus diadema*, the resemblance in general form is at once apparent. The loss of the vestigial second tooth in *Necrolemur* would give the formula of the Indrisinæ, which is seven teeth in the lower jaw. *Necrolemur* differs from *Tarsius*, moreover, in the more advanced condition of the molars. In the lower jaw the anterior cusp of the trigon, figure 148, has completely disappeared, and in the upper jaw the molars are almost fully quadritubercular. *Microchœrus* in all probability comes in the same group, and when more fully known should furnish a closer approximation to the Indrisinæ than *Necrolemur*, on account of the development of a mesostyle in the upper molars. A further character in which *Necrolemur* resembles the Indrisinæ is the lack of differentiation of the anterior teeth into incisors and canines, as well as their tendency to the procumbent position.

Paleontological Laboratory, Yale University Museum,
New Haven, Conn.

ART. XIX.—*Notes on a New Meteorite from Hendersonville, N. C., and on additional pieces of the Smithville, Tenn., Fall;* by L. C. GLENN.

LAST spring Dr. W. H. Jarman of Nashville added to the Jarman collection in geology here a stony meteorite which had been presented to him by Capt. C. F. Toms of Hendersonville, N. C. The writer immediately wrote to Capt. Toms asking for all the information he could give as to the time, place and circumstances of the fall or find. The following extract from his reply contains all the information obtainable on these points. "About the year 1876, when I was quite a boy, a meteor passed over this town from east to west. My father describes it as being as large as a 'wash pot' and it appeared to break into three pieces near the spot where this piece came from. It was very bright, lighting up the whole country and exploded with a great roar like a cannon. In 1901 Wm. Corn, a citizen living near the place, about three miles northwest of Hendersonville, brought this piece to us and we recognized what it was. He found it in the vicinity of what is known as the county home for the aged and infirm, probably on the land belonging to it."

The meteorite as received weighed 11 pounds and 6 ounces. The original weight, however, had been perhaps two pounds greater than this, as two pieces had been broken off before it reached the writer's hands. From one corner a large piece had been broken off, and from another a small flake had been removed. Concerning these pieces, Capt. Toms says, "The pieces broken off were used to make an assay (which has been lost) and therefore cannot be had."

The shape of the mass received was somewhat cubical, though one face of the quasi cube was considerably modified by an irregular portion projecting above it. The exact shape of this projecting portion cannot now be ascertained, as from it had been removed the larger of the two missing pieces above referred to. When resting on a face that may very conveniently be regarded as the base, it stands $6\frac{1}{8}$ inches high, is $5\frac{7}{8}$ inches wide and $5\frac{1}{2}$ inches thick. Its extreme diagonal length is 8 inches. The edges are all either gently or acutely rounded. A considerable portion of the surface is smooth and nearly flat, while the rest of the surface is covered with irregular, shallow pittings or undulations.

The underlying surface color is almost black, but it is generally obscured by rust-colored areas, due to weathering. On broken surfaces it is seen that weathering has produced a rusty-

colored layer a thirty-second to a sixteenth of an inch thick over most of the surface. While there are no cracks in the mass, yet the interior shows that weathering influences have made themselves felt to some extent at least through probably the entire mass. Freshly broken surfaces show a very dark gray mass with many minute rust-colored specks and numerous small masses of metallic luster and either a gray or a light pyritic yellow color.

A piece weighing one and a half pounds was removed and retained and the rest of the mass was given in exchange to the U. S. National Museum, and Professor G. P. Merrill will doubtless soon publish a description of the mineralogical and other characters of the stone. The fall is new and adds one more to the already considerable list of meteorites known from North Carolina.

Three pieces of meteoric iron from Smithville, Tenn., are mentioned by Huntington* in his description of the find. A fourth piece was sent, so the writer has been informed, to the U. S. National Museum. During the past year two additional pieces have come into the possession of the writer. They were found about forty years ago at Berry Cantrell's, one mile west of Smithville, Tenn. The larger mass weighed 3460 grams and was of compact rounded shape and evidently entire. The smaller weighed 478 grams and had had a portion removed by some one. The character of the masses was similar to that described by Huntington and, although the place where they were found was not just the same as that where the previously reported masses came from, they all belong undoubtedly to the same fall, which may have been scattered over a considerable area. Huntington's suggestion of collusion in these Smithville finds and his regarding them as being really part of the Cocke County iron, do not seem to the writer from his knowledge of the circumstances to be at all well taken. No object can be seen in any one going to the trouble of securing portions of a fall, carrying them several hundred miles across the mountains, secreting them forty or fifty years and then making presents of them to strangers! The only reasonable conclusion is that the Smithville finds fell near Smithville and not in a far distant corner of the state.

* Huntington, O. W., Amer. Acad. Arts and Sci. Proc., vol. xxix, pp. 251–260, 1894.

Vanderbilt University, Jan. 19, 1904.

ART. XX. — *Periodic Migrations between the Asiatic and the American Coasts of the Pacific Ocean;* by JAMES PERRIN SMITH.

THE fossil marine faunas of the western coast of the United States, of British Columbia, Alaska, Japan, and India are fairly well known, especially in the Mesozoic era. These faunas are now similar, now different in the various provinces, or in parts of them, presenting an apparently inextricable confusion not capable of any rational explanation. But this confusion is only apparent, for when studied in succession, a regular scheme can be traced in the relationships and diversities of this ancient region. And the changes that are noted point to changes in physical geography that would be insignificant in themselves, compared with continental uplifts and subsidences, though by no means insignificant in their effects. Also there is abundant independent physical evidence that these changes really took place, so they are in no sense merely hypothetical.

Briefly stated, the facts are these. There is at present a remarkable similarity in the living marine molluscs of the western coast of North America and of the eastern coast of Asia in approximately the same latitudes, and this similarity can be traced back with certainty until the Lower Trias, and probably even below that. But the resemblance is not continuous, there being periods in which the faunas were unlike, and these periods of interruption recur several times, although not regularly. It is clear that no migration is taking place between the opposite sides of the Pacific now, and equally clear that such migration did go on in comparatively recent geologic time, when a large part of the present species of marine invertebrates already existed. It remains to state the facts in succession, and then to show how the intermigration must have taken place, and the cause of the periodic interruptions, reasoning back always from modern conditions to those of the past.

Ancient Faunal Relations.

Paleozoic time.—We know little with certainty of the faunal geography of the Paleozoic of the western coast of America except that during the Carboniferous the connection seems rather to have been with northern Asia than with the interior of North America. The kinship of American and Asiatic forms can not be charged to universality of faunas or physical conditions, for we know that there was nearly as much provincial differentiation in the marine Carboniferous as there is now.

Lower Trias.—The writer* has already shown in several papers that the Lower Trias of California and the Great Basin shows an intimate relationship to that of Asia, and none with that of the Mediterranean region. Many genera are represented by closely allied species on both sides of the Pacific Ocean that are wholly unknown in Europe at that time; such are *Flemingites*, *Ophiceras*, *Proptychites*, *Lecanites*, *Aspidites*, *Clypites*, *Pseudosageceras*, *Ussuria*, and many others. Some of the species of these may even be identical, but even without this the association of the genera is such that a paleontologist from Asia would feel himself to be perfectly at home while collecting in eastern California or in Idaho. In some respects the relationship of the fauna of the western coast seems to be closer with that of northern Asia than with that of India; for instance, *Pseudosageceras* and *Ussuria*, which are not uncommon in the Meekoceras beds of the Inyo Range in California, and the Aspen Mountains of Idaho, have never been found anywhere else except at Ussuri Bay in eastern Siberia, from which place they were first described. These genera are probably not of American origin, and most of them are of unknown antecedents. But, fortunately, the geologic history of some of these forms is known. *Ophiceras*, *Xenaspis*, *Xenodiscus*, and *Hungarites*, which occur in the Trias of Asia and America, chiefly in the lower beds, have also been found in the Permian of southern Asia. To this region, then, we must look for the source of the Lower Triassic ammonites which appear as immigrants in the American waters, marking the first distinct Asiatic invasion.

After the deposition of the Meekoceras beds, a few species with Mediterranean affinities begin to make their appearance in western America. But it is noteworthy that, at this time, the Indian still appears to have been cut off from the Mediterranean region.* The geographic regions described by E. von Mojsisovics† for the Trias will hold good only for the Lower Trias, and probably not even for the whole of that period.

Middle Trias.—In the Middle Trias a certain kinship still persists between the marine faunas of western America and Asia, though this may be due as much to inheritance from similar ancestors, as to immigration. No species are any longer common to the two regions, and many genera, even, are different on opposite sides of the ocean. But at the same time a kinship between the American and the Mediterranean faunas begins to be noticeable, especially in the nodose ceratites and other members of the Ceratitidæ. It is possible that during

* Jour. Geol., vi, 776–786, 1898; Jour. Geol., ix, 512–521, 1901.

† Arktische Trias-Faunen, pp. 147–155, 1886, and Beitr. Kennt. obertriadischen Cephalopoden-Faunen des Himalaya, pp. 114–128, 1896.

the Middle Trias a connection was established between these regions through some other way than the Indian branch of the old central Mediterranean, or "Tethys," but we have no way of knowing this passage. It seems possible, however, that it may have been through the Boreal region. The writer* has already given a suggestion of the faunal change at the end of the Lower Trias, based on his own collections made in Nevada during the summer of 1902. No species are thought to have been absolutely identical with European forms, but many are so similar to species long known from the Alps that some sort of connection is beyond question.

Upper Trias, Subbullatus beds.—The writer† has brought out several years ago the relationship of the Trias of California to that of the Alps. Further study, in field and museum, has served only to strengthen this hypothesis, and recent work in India has given a means of comparison with that region, showing that the same thing is true there also.

The Karnic horizon, zone of *Tropites subbullatus*, contains many elements common to the Mediterranean region and western America, and many of these are also found in India. *Tropites subbullatus*, *T. torquillus*, *Paratropites Sellai*, *Entomoceras sandlingense*, *Sagenites Herbichi*, *Polycyclus Henseli*, and *Halobia superba* are common in both California and the Tyrolean Alps, and many other species are very closely related. Most of these are represented in India by forms that may be identical with them, although complete publication of recent geologic explorations in India must be awaited before a final decision can be made.

Now it is well known that the Tropitidæ appeared as immigrants in the Mediterranean and the western American regions in the Upper Trias, without local ancestors. They also appeared at the same time in India, but since we do not yet know the faunas of the upper part of the Middle Trias in that region, there is still a possibility that the Orient may have been the source of this part of the fauna, for it is highly probable that the Indian province was the connection between Europe and America. This Karnic fauna, however, is not yet known elsewhere in Asia, and the only proof we have of the migration is the occurrence of similar species in the widely separated regions. The path of this migration cannot be traced, for fossils of the zone of *Tropites subbullatus* are known in America only in California, not having been found at any other place in either North or South America.

Upper Trias, Noric horizon.—Fossils of the Noric horizon,

* Centralblatt für Mineral. Geol. und Pal., pp. 689–695, 1902.

† The Metamorphic Series of Shasta County, California, Jour. Geol., ii, 588–612, 1894.

zone of *Pseudomonotis ochotica*, are known in Alaska, British Columbia, California, Nevada, and as far south as the coast of Peru. *Pseudomonotis ochotica* is widely distributed in Siberia and Japan, and is probably identical with the American *Pseudomonotis subcircularis*. This group is distinctly Asiatic in origin, and never reached the Mediterranean waters. Its appearance in America marks another Asiatic immigration, but this time it came from the north. We see here a reversion to the conditions of the Lower Trias, but on the Asiatic side the immigrants do not seem to have reached any further than to Japan. The widespread occurrence of beds with *Pseudomonotis ochotica* around the northern shores of the Pacific and around the Arctic Ocean shows a transgression of the sea on what was formerly a continental border. These forms were endemic in the Boreal region, and made their way southward when the transgression of the sea opened the way, on both sides of the Pacific. Of course, this may not have had anything to do with climate, but at the close of the Karnic epoch the fauna of western America shows a sudden change of facies from the Indian-Mediterranean character to that of Siberia, which shows, at least a change in connections. A passage from the Arctic to the Pacific was reopened between Asia and America, and the Boreal, though not necessarily cold-water, type came through, making its way southward.

Deep water, cutting off Asia from America, would have separated the two Triassic regions just as effectively as cold water, but since there was free passage for the group of *Pseudomonotis ochotica* down both sides of the Pacific, it is strange that it did not reach Tropical India, and that the Tropical Indian forms ceased temporarily to come to America. If such changes had occurred in Tertiary time we would say without hesitation that the Boreal invasion marked an influx of cold water from the Arctic Ocean through the open passage between Asia and America.

The group of *Pseudomonotis ochotica* has also been cited by Suess* from New Caledonia, but this occurrence is doubtful, since Rothpletz† found only *Monatis salinaria*, a Mediterranean type, in that region. It may be, however, that in the Indian Ocean the Boreal and the Mediterranean facies were temporarily united, in which case the presence of *Pseudomonotis ochotica* would not necessarily be a proof of the southward extension of a lower temperature.

A modern instance of the same restricted dispersion is seen in the occurrence of *Purpura lapillus* in the North Pacific.

* La Face de la Terre, ii, 422.

† Perm-, Trias- und Jura-Formation auf Timor und Rotti im indischen Archipel, p. 90.

This species is abundant in the North Atlantic, and has made its way through the Boreal region into the Pacific. On the western coast of North America, where there are no sudden changes in the temperature of the sea water, this species has made its way as far south as Margarita Bay, in lat. 24° N., mean temperature 73° F. On the Asiatic side it has made its way through Bering Sea down the shores of Kamschatka with the cold water, but has been stopped by the sudden change of temperature at Hakodadi, lat. 41° N., Japan, mean temperature 52° F., where the warm Japan current meets the cold current from Bering Sea. That this is not an accident of distribution is shown by the fact that *Purpura lapillus* has, in the Atlantic, a similar distribution, and for the same reasons. On the African side it reaches lat. 32° N., mean temperature 66° F., and on the American side it is barred back by the sudden change of temperature at lat. 42° N., mean temperature 52° F.* There can be no doubt that the temperature, or rather evenness of change of temperature, controls the distribution of *Purpura lapillus* now, and it would seem only reasonable to suppose that similar conditions in the Trias caused the unequal distribution of *Pseudomonotis ochotica.*

Lias.—It is probable that during the Lias the southward migration of the Boreal type of animals was interrupted, for the *Arietites* group, which was characteristic of that epoch in Europe, is known in California and Nevada, as well as in Mexico and South America. It was, however, practically universal, having been found also in the Indian region, though not as yet from the Jurassic Arctic sea. In the Upper Lias the genus *Amaltheus* was widely distributed in Europe and in the Boreal region, but has not yet been found in North America. It is known from New Grenada, associated with a typical Mediterranean fauna. It seems probable that the Lias of California and Nevada is merely a northward extension of the South American type.

Middle Jura.—In California the Middle Jura, like the Lias, appears to have been of Mediterranean type, but in the Black Hills we have a southward extension of a fauna characteristic of northern Europe, and of the region around the northern Pacific Ocean. This boreal type is extensively developed in Alaska and in northern Siberia, and its appearance in the Black Hills marks the beginning of another incursion from the north.

Upper Jura.—The incursion of the Boreal fauna into America which began in the Middle Jura reached further southward and westward in the Mariposa epoch of the Upper Jura, down through California to San Luis Potosi in Mexico.

* A. H. Cooke, Cambridge Natural History, iii, p. 363, 1895.

This fauna is characterized by the genera *Cardioceras* and *Aucella*, which had their home in northern Europe and northern Siberia, and appeared in western Europe only sporadically as the result of incursions. Pompeckj* has shown in several papers that a Polar sea existed in the Middle and Upper Jura and Lower Cretaceous, from which incursions were made from time to time into the more southerly regions, when changes in physical geography made it possible. He has also shown that the *Aucella* fauna had its real home in that region, where it formed a truly genetic series, and that it appeared only sporadically in other regions, where the species speedily degenerated and the fauna becomes extinct unless replenished by another migration.

The suggestion of climatic influence on the dispersion of marine animals in the Upper Jurassic is very strong, for the *Aucella* did not make its way into the Indian Ocean, although the way was probably open. It went only where the conditions of its own proper habitat existed, if only temporarily. Even so conservative a naturalist as J. D. Dana† admits that in Jurassic time there was a cold current to the southeast along the western coast of North America, making possible the migration of *Aucella* from the Boreal into warm temperature or even subtropical waters.

Aucella did, however, make its way into northern India, probably from southern Russia, during a time of extension of the sea in that direction in the Kimmeridge and Tithonian epochs.‡

Lower Cretaceous.—After the Jurassic beds were laid down there was in California a break in sedimentation, and the uplift of the Sierra Nevada took place. But it was orogenic, and although widespread, it did not affect the geographic relations, for with the opening of the Cretaceous the same northern types were still there. *Aucella* was still the most characteristic genus, and along with it were many species of ammonites closely related to Russian species. *Aucella crassicollis* was even identical with a characteristic Russian form. These Knoxville species were probably in part immigrants from the Boreal region, although some of them may have been modified descendants from species that were endemic in the American

* Ueber Aucellen *etc.* N. J. für Min. Geol. und Pal. xiv, 343, 1901 and Jura Fossilien aus Alaska, Verh. k. o. Russ. Min. Gesell. (St. Petersburg), xxxviii, 376, 1901. The Jurassic Fauna of Cape Flora, Franz Josef Land; The Norwegian North Polar Expedition 1893–1896, Scientific Results, p. 141, 1898.

† Manual of Geology, p. 794, 1895.

‡ S. Nikitin, Bemerkungen über die Jura-Ablagerungen des Himalayas und Mittelasiens. Neues Jahrb. für Min., Geol. und Pal., ii, 124, 1889.

waters. Before the end of the Knoxville epoch, while the Boreal forms still persisted, *Lytoceras* and *Phylloceras*, genera that were never found in northern Europe and Asia, appeared in the Cretaceous beds of the western coast of America. These forms seem to have been endemic in the warm regions of southern Europe and Asia, and their appearance marks a resumption of interchange between India and America, around the shore-line formed by closing the gap between Asia and Alaska. In proof that the gap was really closed, it may be said that the flora of the Knoxville beds and of the equivalent Kootanie formation appears to indicate a warm temperate climate,* which would mean that the cold current from the Arctic Ocean had been cut off by a rise of the land.

During the Lower Cretaceous *Aucella* made its way into the Tropics, around the Pacific Ocean, so that its later occurrence gives no evidence of southward extension of Boreal climatic conditions.†

Upper Cretaceous.—With the opening of the Horsetown epoch all reminiscences of the Boreal fauna are gone, and the Tropical character of the inhabitants of the sea on the western coast of America is marked. A close affinity and even identity of species with the Indian fauna characterizes this epoch. And it is noteworthy that the Puget Sound Horsetown and Chico faunas are even more closely allied to those of India than are those of California. Migration appears to have been free between Asia and America, but the species did not all range so far south as California, thus indicating the direction from which they came. Of course, not all the marine forms on the west coast of North America came from Asia, but the Asiatic portion is the only one that we can trace to its source.

The following species that occur in the Horsetown and Lower Chico of western America are regarded by Kossmat‡ as identical with species in southern India:

Lytoceras Kayei Forbes.
L. —— *timotheanum* Mayor.
L. —— *cala* Forbes.
L. —— *indra* Forbes.
Hamites glaber Whiteaves.
Schloenbachia inflata Sowerby.
Acanthoceras Turneri White.
Pachydiscus otacodensis Stoliczka.
P. —— *arialurensis* Stoliczka.
Desmoceras diphylloides Forbes.

* T. W. Stanton, Jour. Geol., v, 599, 1897.

† Pompeckj, Ueber Aucellen und Aucellen-ähnliche Formen, Neues Jahrb. für Min. etc., xiv, 348, 1901.

‡ Beitr. Pal. und Geol. Oesterreich-Ungarns und des Orients, ix, Parts 3 and 4, 1895.

Desmoceras latidorsatum Michelin.
Puzosia planulata Sowerby.
Hauericeras Gardeni Bailey.
Phylloceras Whiteavesi Kossmat.
P. —— *Velledae* Michelin (cited as the probable equivalent of *P. ramosum* Meek).

Besides the above, F. M. Anderson* describes the following species from the lower Chico beds as identical with Indian forms: *Schloenbachia propinqua* Stoliczka, *S. blanfordiana* Stoliczka, *Desmoceras sugata* Forbes. Nearly all these species that are common to the western coast of America and India also occur in Japan, and many of them also in eastern Africa. They are, then, tropical or subtropical in habitat. Whether the appearance of the *Aucella* fauna of the Upper Jura and the Lower Cretaceous in the North Pacific meant cold water or not, the appearance of the Indian forms in the same region can only be interpreted to mean that a warm temperature prevailed there at that time, and that conditions were equable around the old shore line from India as far as California.

With the closing of the passage between Asia and America, the warm Japan current, which is now chilled by the cold southwesterly current from Bering Sea, would warm up the whole coast line and make the waters of western America warmer than they are now. We also have evidence that the temperature of the land in the northern hemisphere was warmer than at present, for Heer† has shown that the Cretaceous floras of Greenland, Spitzbergen and Alaska contained cycads and other forms indicating a mean temperature of about 70° F.

Upper Chico.—In the upper Chico horizon (Senonian), of California and Oregon the connection with India appears to cease, and a path of migration from the interior Cretaceous sea of America seems to have been opened.‡ Several species of pelecypods are identical with species from the upper Missouri province, and some of the ammonites are closely allied.

Eocene.—During the early Tertiary, or Tejon epoch, in California we have no evidence of any migration from Asia, but it is plain that a connection existed with the Eocene sea of the Atlantic region. *Venericardia planicosta*, which is abundant in the Claiborne beds of the states around the Gulf of Mexico, has been found at a number of places in Oregon and California, and it appears to be more common in southern California than anywhere else on the western coast. Other

* Cretaceous Deposits of the Pacific Coast, Proc. Calif. Acad. Sci., iii, Ser. Geol., vol. ii, No. 1, 1902.
† Flora Fossilis Arctica, vi and vii. 1882–83.
‡ F. M. Anderson, Cretaceous Deposits of the Pacific Coast, p. 59, 1902.

species of this fauna may be identical with Atlantic forms, at any rate some are closely related, and it is probable that the passage lay to the south of California.

Miocene.—In the middle Tertiary the passage to the Atlantic seems to have been closed, and there is no evidence that communication was resumed with Asia. The Miocene fauna of California seems to have been largely endemic, for no Atlantic species are found in it, and the only possible admixture consists of forms from the south, and of circumboreal species that made their way down from the north. But towards the end of Miocene time the land appears to have risen in the north, cutting off the Arctic Ocean from the Pacific, and allowing land plants to migrate from Asia to North America. Asa Gray* has shown that in the Miocene northeastern Asia and northwestern America were connected, that over those regions there existed a flora like that of warm temperate latitudes at the present time, and that this connection persisted almost to the beginning of the Glacial epoch.

We have no evidence that a migration of marine invertebrates from Asia began as early as the upper Miocene, but they would naturally be slower in their movements than land plants, and consequently would lag behind them. The Tertiary uplift of land in the northern hemisphere may be correlated with the widespread orogenic uplift of the Coast Ranges on the Pacific side of North America, which in California and Oregon is known to have come at the end of the Miocene, and before the Pliocene beds were laid down.

Pliocene.—There is good geologic evidence that the land-bridge between Asia and America still existed in the Pliocene, for there seems to have been a constant interchange of vertebrates in that quarter,† in the Miocene, Pliocene, and early Pleistocene. Also students of other groups find it necessary to postulate such a connection to explain the migration of animals. A. E. Ortmann‡ says that the identity of some of the fresh-water crustaceans in Siberia and Alaska proves a recent connection of those parts, and that this union of the continents began in the middle of the Cretaceous and lasted into the lower Pleistocene. G. M. Dawson§ is of the opinion that in the Pliocene the Pacific coast of North America stood about 900 feet higher than now, which would be ample to connect the two continents, and cut off the cold water from the North Pacific. And we still have evidence of this former elevation of the Alaskan region, for in the Aleutian Islands,

* Amer. Jour. Sci. (3), cxvi, 195, 1878.
† H. F. Osborn, Science, xi, 571, 1900.
‡ Proc. Amer. Phil. Soc., xli, 291, 299 and 316, 1902.
§ Quoted in Dana's Manual of Geology, 949, 1895.

commonly regarded as a chain of new volcanoes, granite appears in several places.*

At this time the marine faunas of Japan and the western coast of America begin to be remarkably similar, with many species identical, which can only mean that intermigration had set up along the shore line. And the identical species are not merely circumboreal, for many of them have never been found in the Bóreal region. A list of these, and their geologic range, will be found on the table on page 229.

The rise of the land in the northern hemisphere, as shown by the distribution of land and fresh-water animals, would cut off the southward cold current from the Arctic Sea, and prevent the chilling of the Japan current south of Bering Sea. The Japan current would then warm the shores of Alaska, and produce a mild temperature along the old shore line from Japan to California. That it did so is shown by the similarity of the Pliocene faunas of the two now separated regions. At first there was naturally a mixture of Boreal and Japanese forms, for D. Brauns† has shown that the Pliocene of Japan is related to the "Crag" of England; and the upper Pliocene of California appears to indicate a temperature of the sea-water somewhat lower than at present. At any rate, it is clear that the climate around the North Pacific in Pliocene time was merely temperate; this is shown by the fact that while we have an immigration of Japanese species, no Indian forms came with them, as they did in the Upper Cretaceous, when the climate appears to have been subtropical.

Pleistocene and Recent Faunal Relations.

San Pedro epoch.—With the beginning of the Pleistocene the same conditions existed as in the upper Pliocene. Japanese species still abound in the marine fauna, and the character is still somewhat boreal,‡ which may be due to a survival of forms that came in during the colder Pliocene epoch. The land connection with Asia still existed, and free exchange of land animals between Asia and America still went on.

As the waters of the Californian coast gradually became warmer, Mexican species began to creep northward, and in the upper San Pedro fauna we find a number of species that now live only in the Tropics, and have become extinct on the Californian coast.§ This does not mean that connection with Japan

* J. E. Spurr, U. S. Geol. Survey, 20th Ann. Rept., Part vii, 234, 1900.

† Geology of the Environs of Tokio, Mem. Science Dept., Univ. of Tokio, No. 4, pp. 1–82, 1881.

‡ Delos and Ralph Arnold, The Marine Pliocene and Pleistocene Stratigraphy of the coast of Southern California, Jour. Geol., vol. x, No. 2, pp. 117–138 (1902).

§ Ralph Arnold, Mem. Calif. Acad. Science, iii, 29 et seq., 1903.

was cut off, but that the continuation of the conditions that allowed Japanese species to migrate to California finally allowed marine animals to make their way up the coast also.

Glacialists postulate an elevation of the land in the northern hemisphere, in the period preceding and during the Glacial epoch; this undoubtedly cut off the migration of land animals and plants between Asia and America. When this affected intercommunication along the shore-line we do not know, but after the close of the San Pedro epoch the Asiatic immigration ceased, and also the subtropical elements of the marine fauna of California became extinct. With the subsidence following the Glacial epoch conditions returned to the normal, and intermigration with Japan was not resumed. It was too cold for the perpetuation of the warm-water species from the south, though not too cold for the Japanese species to live on in the Californian waters. But the Asiatic colonists in America were not replenished by immigration from the mother country, and those that are found in the Californian province are merely survivors.

Relations of the living faunas of the west coast to that of Japan.—The table on page 229 shows the living species that are common to the western coast of North America and the Japanese province. The number of species is very large, especially when we consider the fact that they are in different zoölogic regions, and separated by more than five thousand miles. Migration of shore forms can not possibly be going on now, for while the distance is no bar to them, the deep water at the end of the Aleutian chain of islands would effectually check all passage in either direction. And the sudden changes in temperature through which marine animals would have to pass are an equally effectual barrier. We have seen already how even a circumboreal species, as *Purpura lapillus*, is checked in its southward passage where the cold current from Bering Sea meets the warm Japan current. Such changes are even more impassable to warm-water species.

In the present similarity of the marine faunas of Japan and the western coast of America we have an example of provinces that were recently connected, but which are now separated by deep water and by differences of temperature in between, while the conditions still remain similar in the two provinces. This separation, however, has existed long enough for some of the species to have become differentiated by evolution, for some to have become extinct in one province while still living in the other, and for the total faunas to have become much changed by immigration from other regions.

At first sight it would seem that the intermigration of the marine faunas has been more recent than the exchange of the

land animals and plants between Asia and America. And indeed this may be so, for a subsidence that would cut off effectually all land organisms might not interfere with the migration of marine animals living at moderate depths. For instance, *Haliotis*, a distinctly Asiatic type, is not known on the west coast of America before the upper San Pedro epoch, and has now made its way southward below California. On the other hand, we must remember the conservative character of marine faunas. Where in the land Pleistocene faunas most of the species have been replaced by others, of the marine Pleistocene animals only a very small percentage has become extinct. We must also note that, of the species now common to the two sides, a large proportion is known to have existed in Tertiary time, and probably nearly all in Pleistocene. In the time that has elapsed since the two provinces were separated, *Lucina acutilineata*, which abounded during the Pliocene in both Japan and California and is still living in Puget Sound, has become extinct in Japan. *Mya arenaria*, also abundant in the Pliocene in both provinces, has become extinct in California, while it still persists in Japan. It has, however been introduced artificially late in the nineteenth century and now abounds in most of the bays on the west coast. On the Alaskan coast *Mya arenaria* did not become extinct, though it did not make its way down to California. It is also probable that *Pecten caurinus* on the west coast and *P. jessoensis* in Japan have become differentiated from their common ancestors.

All this points to a rather ancient separation, not later than the upper San Pedro epoch, at which time the warm-water fauna came up from the south, and never reached Japan.

Summary.

Present physiography.—The living faunas of the Japanese province and of the western coast of North America are rather closely allied, with a large number of species in common, and they live under approximately the same conditions, although they are in widely separated regions. Between them lies a stretch of shore-line running up to lat. 60° N., around the southern shores of Alaska and the Aleutian Islands, but interrupted by the deep channel east of Kamchatka. Also there is a great difference of temperature between them. The warm Japan current, with an average maximum temperature of 86° F., flows past Japan, swings to the northeast, south of the Aleutian chain towards America, and parts off Puget Sound, one branch flowing northwestward along the Alaskan coast, and the main branch southeastward down towards California.

TABLE SHOWING LIVING SPECIES COMMON TO THE WEST COAST AND JAPAN.

	Japanese Province.			West American Province.		
	Plio-cene.	Pleis-tocene.	Living.	Plio-cene.	Pleis-tocene.	Living.
Barbatia gradata Sowerby			×			×
Cardium blandum Gould			×	×	×	×
Cardium corbis Martyn	×		×		×	×
Chlamydochiton annulatus Pallas			×			×
Crepidula grandis Midd.			×	×		
Cryptochiton Stelleri Midd.			×			×
Diplodonta orbella Gould	×		×		×	×
Dentalium hexagonum Sowerby	×		×	×	×	×
Haliotis Kamtschatkana Jonas	×		×			×
Laqueus californicus Koch			×	×	×	×
Lasæa rubra Montagu	×		×		×	×
Leptothyra Carpenteri Pillsbry			×			×
Lima orientalis Adams	×		×			×
Littorina sitkana Philippi			×			×
Lucina borealis Linné	×			×	×	×
Macoma edulis Nuttall						
Macoma inquinata Gould			×			×
Macoma nasuta Conrad	×		×	×	×	×
Macoma secta Conrad			×	×	×	×
Modiola flabellata Gould	×			×		
Macron Kelletii A. Adams			×			×
Mopalia muscosa Gould			×			×
Murex foliatus Gmelin			×		×	×
Mya arenaria Linné	×		×	×		
Mytilus edalis Linné	×		×		×	×
Nuonla Cobbeldiae Sowerby	×		×			
Natica clausa Broderip			·×		×	
Panopæa generosa Gould	×		×	×	×	×
Pecten caurinus Gould	?		?	×	×	×
Pecten jessoensis Stimson	×		×			
Pecten hericeus Gould			×	×	×	×
Pecten islandicus Müller			×	×	×	×
Placuanomia macroschisma Deshayes			×	×	×	×
Purpura crispata Chemnitz			×	×	×	×
Purpura lapillus Linné	×		×	×		×
Sanguinolaria Nuttalli Conrad			×			×
Saxidomus Nuttalli Conrad			?	×	×	×
Siphonalia Kelleti Hinds			×		×	×
Siliqua patula Dixon			×			×
Solen sicarius Gould			×	×	×	×
Tapes staminea Conrad			×	×	×	×
Tellina bodegensis Hinds			×	×	×	×
Terebratulina caput-serpentis Linné	×		×			×
Tresus Nuttalli Conrad	×		×	×	×	×
Tritonium oregonense Redfield			×		×	×
Trophon orpheus Gould			×	×	×	×
Velutina laevigata Pennant			×		×	×
Venus Kennerlyi Carpenter			×			×

But in lat. 42° N., off Hakodadi, Japan, it is met by the cold current from Bering Sea along the coast of Kamchatka, and from there on the current is merely temperate, being reduced

to about 66° F. It tempers the Alaskan waters, but makes the waters along the shores of California colder than they should be, as compared with similar latitudes elsewhere. These currents have been fully described by Professor George Davidson,* who has made many hydrographic investigations in that region; and by Dr. W. H. Dall,† who verified much of the work of Professor Davidson, but showed that there was no northward branch of the Japan current extending up into Bering Sea.

At present the migration of shallow water species is stopped by the depth of the channel at the end of the Aleutian chain, and also by the cold water that extends southwestward from Bering Sea. But a rise of 200 meters would close Bering Strait, and about one-half of Bering Sea, giving a shore-line coinciding approximately with a great circle. It would then leave the Aleutian chain as a long narrow peninsula reaching out from Alaska towards Siberia, separated from Kamchatka by a rather narrow but deep channel; while the mainland of Alaska and Siberia would be united by a broad land-bridge. This change in the height of the land would cut off all influx of cold water from the Arctic Sea, and the Japan current, not being chilled by cold water from Bering Sea, would still be warm along the Aleutian Islands and the Alaskan coast, and no doubt the tempering effect would be felt even as far south as California. A rise of 2,000 meters would not connect the Aleutian chain with Kamchatka, but at least would give a stretch of shoal water along which migration would be easy for shore forms. In any case there would be a shore line with temperate or warm water all the way from Japan to California.

While it is not likely that the land in the northern part of the Pacific has, in recent geologic times, stood 2,000 meters higher than now, it has certainly stood several hundred feet higher, and whether much or little, we know from the migrations of land plants and animals between Asia and America that there has been a land-bridge. Now in any case, whether in the present or in the past, similar contemporaneous faunas mean similar conditions, and identical species mean immigration from one region to the other, or from a third region to both. In the case of Japan and the west coast of America the only outside region that can have furnished elements to both is the Boreal region, and circumboreal species in both provinces are well known. But a large majority of the species now common to both provinces are not circumboreal. Thus intermigration is the only satisfactory explanation of the pre-

* Report Supt. U. S. Geodetic Survey, 1867, Appendix No. 18, p. 202, 1869.

† Rept. Supt. U. S. Coast and Geod. Survey for 1880, Appendix No. 16, p. 322.

sent distribution of most of the species that are common to Japan and California.

Unlike species living contemporaneously in similar conditions can only mean separation by physical barriers; these to the marine shore-animals are: a land-mass; deep water; or great difference of temperature in between. The two latter are the only barriers that can ever have been interposed between Japan and the west coast of America, and a rise of 200 meters would remove both.

The hypothesis of former migration around the Alaskan-Aleutian shore-line explains satisfactorily the close relationship between the living marine animals of Japan and California, while the present interruption and the length of time during which it has persisted explain the unlikeness of the greater part of the two faunas. A periodic recurrence of this interruption accounts for the periodically recurring unlikeness of faunas of these two provinces in the past, and also for the fact that the successive faunas of California do not form a genetic series, but rather one showing periodically diverse origin and characters. With this in mind we can find out where the successive migrations came from, and why the present fauna shows such a commingling of forms derived partly from Asia and partly from the more southerly regions of America.

Past physiography.—The old idea of uniformity of climate all over the earth before the Tertiary period still remains as an undercurrent in the minds of geologists, and stands in the way of any theory that accepts the influence of differences of temperature in causing faunal differences in the past. Stanton* denies that the change of character of the Cretaceous fauna of the west coast at the end of the Knoxville epoch, from the Boreal to the Indian type, can be attributed to change in climate. Others have criticized Neumayr's† theory of climatic zones in Jurassic and Cretaceous times, and there can be no doubt that Neumayr carried his theories entirely too far, reconstructing ancient physical geography on very little evidence. But the fact that Neumayr was mistaken in many things is no argument that the principle was wrong. No doubt geographic connections and presence or absence of opportunities for free intercommunication were of just as great importance as differences of temperature in governing the distribution of faunas in the past, as well as now. But it will not do to leave climate entirely out of the reckoning.

The assumption of a uniform temperature over the earth before the Tertiary period rests on an insecure basis. If any

* Jour. Geol., v, 598, 1897.

† Klimatische-Zonen während der Jura- und Kreidezeit. Denkschr. k. Akad. Wiss. Wien, xlvii, 1883.

former climate was uniform, it must have been warm, and the temperature must have been warmer the further we go back in geologic history. And yet we have evidence that the temperature was not uniform even in the Paleozoic. It is well known that over parts of India, Australia and South Africa there is good evidence that there was a Permian glacial epoch, while we know from abundant contemporary floras in other parts of the earth that this glaciation was not universal. In South America in the same latitudes as the glaciated region of the Orient there does not appear to have been a cold period. In this, then, we have proof that there was great diversity of climate even in the Paleozoic era.

Now it would be absurd to account for the difference between the cold-water faunas of California in the Pliocene and lower San Pedro formations and the warm-water fauna of the upper San Pedro, and the contrast between the latter and the present cooler water fauna of the California coast, on any other hypothesis than differences of temperature. For all this is based on species that are still living, where we know the exact conditions of geographic connection and temperature under which they live, and by which their distribution is governed. These differences of temperature are slight, and the changes in physical geography that caused them are insignificant, though far-reaching in their effects. All this, of course, applies only to the shore lines affected by the marine currents, and does not necessarily have anything to do with continental climates.

It would seem equally rational to explain similar distribution in the past by the same hypothesis. The faunal relations between western America and eastern Asia from the Trias to the present were the same, Asiatic facies alternating with periodically recurring invasions of the Boreal type. If differences of temperature can account for the connections and separations of the living faunas, they must be taken into account in explaining similar connections and separations in Tertiary, Cretaceous, and even Jurassic and Triassic times.

On homotaxis.—The similarity of the fossil faunas of the Orient to those of the west coast of America is, indeed, surprising, but not more so than that of the living faunas of Japan and the Californian province. It is important in the correlation of these deposits to determine whether they are really synchronous. Ever since Huxley* cast doubt upon the simultaneous occurrence of the same faunas in widely separated regions, geologists have been inclined to assume that this similarity is good proof that they were not really synchronous. But we know that the present faunas of Japan and the Cali-

* Quart. Jour. Geol. Soc., London, xviii, 40–54, 1862.

fornian province are synchronous and similar, with many identical species, although they are in different geographic regions. And there is no more reason to assume that the similar Mesozoic faunas of the two regions were not synchronous than there is for the present time. The modern instance shows that they may just as well have been synchronous as not.

Biologists are often sceptical as to identity of species in separated regions in the past, on the ground that the criteria for determining fossils are not so exact as those applied to recent forms. But this is also fallacious, since the recent shells of Japan and California have been subjected to most careful examination by critical conchologists, and many species found to be identical. There is, therefore, no presumption against the identity of similar species in the two regions of Cretaceous, Jurassic, or even Triassic age.

On the permanence of the shore-line.—The marine sediments and their fossils around the North Pacific, from the Trias on to the present time, show that the shore-line has been, during all that time, approximately as it is now. There is no reason to theorize about great changes in physical geography, when such a simple matter as the periodic opening and closing of Bering Strait by rising and sinking of the land in that quarter will account satisfactorily for all the changes in character and distribution of the marine faunas. E. Haug,* in his studies of the distribution of Mesozoic formations and organisms, has invented the theory that during Mesozoic time a great continent existed where the Pacific Ocean now is. Whatever may be true of the rest of that ocean, there is no necessity for supposing a continent to have existed formerly in the North Pacific, when all the facts may be explained more easily on the hypothesis of the permanence of the shore-line approximately as it is now. This has nothing to do with the general proposition of the permanence of continental plateaus and oceanic basins, but merely proves a particular case, and suggests that some of the ancient oceans, that are to be found on maps purporting to represent the former continents and seas, may be only epicontinental seas.

* Les Geosynclinaux et les Airies continentales. Bull. Soc. Géol., France (3), xxviii, 646.

Stanford University, California.

ART. XXI.—*Triticites,* a New Genus of Carboniferous Foraminifers;*† by GEORGE H. GIRTY.

WHEN, in the course of preparing a report on the Permian fauna of the Guadalupe Mountains, I came to study the species described by Shumard as *Fusulina elongata*,‡ my attention was engaged by a structural difference of some mark between it and the form from the Coal Measures strata of the Mississippi Valley, commonly identified as *Fusulina cylindrica.* I was consequently led to consider the structure of typical *Fusulina*, and found that the Guadalupian species, and not the common Pennsylvanian one, agrees with the Russian form. The discriminating character which is shown by Fischer-de-Waldheim's original figures of *Fusulina*, by specimens from Russia, and by most figures and descriptions in manuals,§ etc., resides in the partitions which separate adjacent chambers in the same concentric series.

As is well known, each chamber is formed by a narrow prolongation of the outer wall in the direction of revolution, followed by a sharp deflection toward the axis to meet the volution below. The partition thus formed is not, however, complete, minute apertures being left along its lower margin.‖ In true *Fusulina* this partition wall is strongly and regularly fluted in a radial direction, and the arrangement is such that the concave flexures of one partition are opposite the convex flexures of the next, the approaching curves coming in contact more or less precisely along a line. Thus what would otherwise have been a single long chamber extending unobstructed from end to end, is divided into a large number of chamberlets. These are usually quite regular and have the shape of prisms with subrhombic section. The regular fluting of the partitions is often well shown by the aperture, but no intimation of it is conveyed by the straight depressed sutures which prominently mark the external surface. Apparently the fluted structure is not introduced until just after the wall has assumed a radial direction, when it is concealed by the overlap of the succeed-

* From *triticum*, a grain of wheat.

† Published by permission of the Director of the U. S. Geological Survey.

‡ St. Louis Acad. Sci., Trans., vol. i, 1859, p. 388.

§ As, for instance, on p. 31 of Steinmann and Döderlein's Elemente der Paläontologie (Leipzig, 1890), on p. 104 of Zittel's Handbuch der Paläontologie, Bd. I (Munich and Leipzig, 1876–1880), on p. 32 of Zittel's Textbook of Palæontology (London and New York, 1896), on p. 136 of Nicholson and Lydekker's Manual of Palæontology, vol. i (Edinburgh and London, 1889), etc. See, also, Geology of Russia, etc., by Murchison, de Verneuil, and Keyserling, vol. ii, 1845, pl. i, fig. 1*e*.

‖ Indicated by the frequent failure of the partition walls to extend to the preceding volution.

ing wall. Let, however, the outer wall be removed by weathering or by artificial means, and the surface is seen to be very regularly divided into rhombs, which the eye naturally follows in spiral rows.

In the form from the Mississippi Valley for which the name *Triticites* is proposed, the partitions are for the most part straight, and not fluted except in the immediate vicinity of the axis, so that the greater portion of each chamber is not divided into chamberlets. There is also a slight formal difference between *Triticites* and *Fusulina*, since the former seems not to occur in the elongate subcylindrical shapes often found in the latter. *Triticites* is usually subglobose or spindle-shaped, but as *Fusulina* likewise develops these forms, configuration is of but limited importance in discriminating the two genera.

1

Transverse section.
×10.

2

Longitudinal section.
×10.

Externally they will many times look almost precisely alike, except for the aperture, which, if exposed, will at once serve to distinguish them. In weathered specimens the long almost parallel lines of the partitions in *Triticites* are in marked contrast to the reticulation formed by these structures in *Fusulina*. Transverse sections in the two genera are sometimes nearly alike. In each case a spiral wall is seen from which in *Triticites* simple projections extend at regular intervals toward the center, reaching in some cases nearly, and in others completely, to the preceding volution. This is well shown by fig. 1, which represents *Triticites secalicus*. A transverse section through *Fusulina* presents a similar appearance, save that the partition walls are frequently represented by looped or forked lines, instead of by simple ones. The radial walls are seen in many cases to be incomplete, and it is probably by means of the apertures thus left that communication between succeeding chambers was maintained. In longitudinal section the difference is more apparent. The concentric walls of *Fusulina* enclose between them lines, sometimes straight, sometimes curved, often loop-shaped, which are the edges of the inter-

sected fluted partitions, the direction of which is seldom the same as that of the section. In longitudinal sections of *Triticites* there extends along the axial line a band of anastomosing walls, sometimes constituting a more or less regular network, but usually disordered and confused. Aside from this the space between the concentric walls over the median and larger portion of the volutions is uninterrupted, except as some irregularity permits the section to cut one of the longitudinal partitions. Fig. 2 represents a longitudinal section through *Triticites secalicus.* The undivided chambers are well shown in this section, and the wrinkled partitions near the ends of each chamber, which by their recurrence produce a band through the axis. This difference in longitudinal section would probably escape no trained observer, but its significance can be appreciated only when interpreted in terms of the complete organism.

The minute wall structure of *Triticites*, though it does not seem to differ from that of *Fusulina*, deserves to be noticed. The wall in these shells is composite, apparently consisting of two substances, of different character, or, at all events, of different density. Thus, when thin sections are examined, three different tints, with more or less well-marked boundaries, are seen, namely, the transparent calcitic filling of the chambers, the translucent substance of which most of the wall is composed, and an outer opaque layer whose distribution will be described somewhat carefully. This opaque layer is much thinner than that which is translucent, and seems to represent merely an external coating upon the upper and front sides of each chamber wall. It usually appears as a strong dark line in thin sections, which defines the translucent wall of one chamber from that of the next, and it forms a plane of dehiscence along which the chambers and volutions tend to separate. A certain amount of variation is manifest by this layer and its conduct in the partitions is different from that in the revolving wall, an indication of individuality in these structures of which there is further evidence. In the revolving wall it occasionally happens, chiefly in local areas, that no intensification of tint is seen along the outer surface, the whole wall being practically uniform. In other instances an intensification occurs on the inner side nearly equal to that of the outer, but as a rule, from which exceptions are but few, sections clearly show a dark coating upon the outer surfaces of the revolving wall. This layer is seen to be continuous from the revolving wall to the partitions and it thus defines to the eye the limits of each chamber from that adjacent to it. The growth of the shell is, therefore, seen to be the result of a repetition of similar stages, each of which consisted of a prolongation of the shell first in a

revolving and then in an axial direction. While as a rule the dark line of the dense layer defines the external surface of the partition as well as of the revolving wall, the thick inner layer apparently being continuous from one to the other, occasionally it interrupts the latter and as it assumes an axial direction fans out and either divides, so as to bound both sides of the partition, or spreading, involves it in a nearly uniform dark tint. In this case obscure radial lines, probably of structural origin, can sometimes be made out. The partitions, as we shall shortly see, have otherwise a different structure from the revolving wall. The distribution and behavior of this dark coating seems to me to indicate that it is an original and intrinsic feature of the shell structure, and that it does not represent the contact between two walls nor the plane along which testaceous material was deposited from two sides. Somewhat in contradiction, however, stands the fact that where the walls have become detached the dark layer is often not conspicuously

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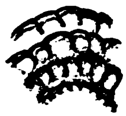
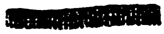


Transverse section.
× 15.

4

Transverse section.
× 25.

5



Microscopic structure.
× 40.

retained upon either of them. Figs. 3 and 4, drawn from *Triticites secalicus*, show the general microscopic structure of the wall, the thin outer dense layer, and the thick inner translucent layer. They show the inner wall as completely surrounding the interior of the chamber. While not of rare occurrence, it is more common for the inner layer to be developed only on the upper and outer portions of the chamber wall, the lower and inner boundary being formed by the dense outer layer of the volution and chamber preceding. It is evident that the complete inner layer, if it is extended from end to end, would cut off all communication between adjacent chambers (except through the pores). The formation of this layer, therefore, over the back and lower walls is probably due to subsequent deposition.

Part of the translucent wall is thickly penetrated by opaque rods or tubuli, whose direction is normal to its two faces, and it is this structure which has caused *Fusulina* to be described as strongly perforate. These rods or tubes are always considerably darker than the translucent wall which they pervade and are as a rule of somewhat lighter tint than the dense outer layer. They usually increase in size inward and taper toward

the opaque layer, and while in some instances they reach and connect with the latter, for the most part they diminish and disappear before completely penetrating the translucent wall. They have the same appearance whether the specimen is cut lengthwise or transversely, and their cross section was probably circular. In their distribution these rods or tubes seem to be confined entirely to the revolving wall. Occasionally they can be seen to extend part way around the turn to where the wall becomes radial, but I have never seen them in the partition wall itself. Fig. 5 represents a section through part of the revolving wall of *Triticites secalicus.* The upper margin of the figure is the outer margin of the wall. The dark lines represent what has usually been interpreted as pores or tubes. These structures can not be seen in the radial walls.

In section, therefore, the revolving wall is seen to be barred off into nearly equal stripes of opaque and translucent shades, and of these it is clear that the translucent ones represent the shell and the opaque ones what have been considered pores.

Carpenter described the minute structure of "*Fusulina*" in 1870, and his conclusions have been followed or concurred in by most subsequent writers. It is interesting to note that his investigations were made upon specimens from Iowa which with great probability belonged not to *Fusulina* but to *Triticites.* One can hardly doubt that he also studied specimens of real *Fusulina*, and it is difficult to understand why he disregarded the differences which have led me to distinguish *Triticites* as a distinct group. Though he does not mention or figure the dark layer which coats the walls upon their outer side and which in sections defines the outline of each chamber, and though other writers have not, whose work has come into my hands, I am quite satisfied as to its existence and persistence.* The interpretation of its significance, on the other hand, is a matter of uncertainty. The presence and conduct of this dark superficial layer and its relation to the so-called tubuli have led me to entertain some doubt as to whether the shell in this genus is as usually stated, perforate.

Carpenter remarks upon the complexity of the partition walls in the terminal portions of *Triticites* in the following terms: "The irregularities which are noticeable in *sections* made either longitudinally or traversely through the terminal portions of the shell, seem explained by the disposition of the alar prolongations which is revealed by *fracture;* for this shows that the alar prolongations, as they pass to a distance from the median plane, tend to interdigitate with each other,

* Material of both *Fusulina* and *Triticites* has been examined, and from a number of localities and horizons sufficient to show that these characters are constantly present and are not the result of peculiar preservation.

in such a manner as to produce great apparent confusion when they are brought into view by section."* While this is perhaps equally true of *Fusulina*, the simplicity of the partitions in *Triticites* over their median portion renders their complexity near the ends peculiarly striking. From the passage above quoted, from Carpenter's figures, and from the localities and horizons from which his American specimens were obtained, there can be no doubt that they belonged to *Triticites*, instead of to *Fusulina*.

I am in some uncertainty about the taxonomic value which should be given to the differences above noted between *Fusulina* and *Triticites*. It is evident that they are of degree only, though very marked in the case of the forms under discussion, intermediate stages being unknown. I would regard *Triticites* in any other group as a good subgenus, though probably no more; but among forms whose simple structure puts a certain limit upon differentiation, it seems that somewhat different standards should be employed, and I believe that the group of *Triticites* can be given generic rank.

The type of *Triticites* is not a new species. In 1823 Say† described two species from Kansas and Nebraska under the name of *Miliolites secalicus* and *Miliolites centralis*, which from evidence intrinsic and extrinsic belong without question to the group of fossils for which the name *Fusulina cylindrica* has since come into general use. J. W. Beede‡ was, I believe, the first to recognize the real character of *Miliolites secalicus* and to revive this specific name for the American form, but he did not discriminate it from *Fusulina cylindrica* Fischer-de-Waldheim, which he relegated to synonymy. While I had little doubt that the American species was distinct from the Russian one, I have continued to use for it the name *Fusulina cylindrica*, because it seemed to me undesirable to disturb the current terminology until several essential points could be determined with reasonable finality. In the present paper I have sought to show that the American form is not only specifically distinct from *Fusulina cylindrica*, but can probably be referred to a different genus, for the type of which *Triticites secalicus* is selected. This species was first described from the Missouri River near the Platte. The material upon which my interpretation of *Triticites secalicus* is based, and upon which the term *Triticites* immediately rests, was obtained from the Platte River near its junction with the Missouri. The locality and horizon, therefore, can be said to be essentially the same,

* Monthly Microscop. Jour., vol. iii, 1870, p. 182.

† Account of an Expedition from Pittsburgh to the Rocky Mountains, etc., under Major Stephen H. Long, vol. i, 1823, p. 151, footnote.

‡ Univ. Geol. Surv. Kansas, Rept., vol. 6, 1900, p. 10.

and as my material agrees with Say's description as far as it goes, I have little doubt that it is the same species for which the name was first employed. My investigations have been carried sufficiently far to show that most if not all of the so-called *Fusulinas* of the Mississippi Valley belong to *Triticites.* I am not prepared to express an opinion as to whether several or, as has generally been assumed, but a single species occurs there. The second species described by Say, under the name of *M. centralis*, is doubtfully distinguished by the characters pointed out by its author. Say's description of *Miliolites secalicus* is framed in the following words, and can be amplified from the descriptions and figures here presented:

"29. On the Missouri near the Platte occur masses of rock, which seem to be almost exclusively composed of a remarkable petrifaction, belonging to the family of concamerated shells. This shell is elongated, fusiform, and when broken transversely, it exhibits the appearance of numerous cells disposed spirally as in the *Nummulite*, but its longitudinal section displays only deep grooves. The shell was therefore composed of tubes or syphons, placed parallel to each other, and revolving laterally as in the genus *Melonis* of Lamarck, with which its characters undoubtedly correspond. But as in the transverse fracture, its spiral system of tubes cannot be traced to the center in any of the numerous specimens we have examined, it would seem to have a solid axis, and consequently belongs to that division of the genus that Montfort regards as distinct, under the name of *Miliolites*, which seems to be similar to the *Fasciolites* of Parkinson, and altogether different from the Miliolites of Lamarck. Our specimens are conspicuously striated on the exterior, which distinction, together with their elongated fusiform shape, sufficiently distinguish then as species from the *sabulosus* which Montfort describes as the type of his genus. No aperture is discoverable in this shell, but the termination of the exterior volution very much resembles an aperture as long as the shell.

The length is three-tenths of an inch. And its greatest breadth, one-twelfth.

We call it *Miliolites secalicus, Say.* Mr. T. Nuttall informs me, that he observed it in great quantities high up the Missouri.

In the same mass were some segments of the Encrinus, and a Terebratula with five or six obtuse longitudinal waves."

Art. XXII.—*Prismatic Crystals of Hematite;* by G. W. McKee.

The common forms for hematite crystals are rhombohedra and scalenohedra. Prismatic faces are seldom well developed. The basal pinacoid is still rarer. Specimens of well crystallized hematite showing crystals of an unusual habit were obtained recently from Dr. A. E. Foote, Philadelphia. These specimens are reported to be from Guanajuato, Mexico. The crystals, which are very small, seldom more than a millimeter in diameter, are well formed and possess a bright metallic lustre such as is characteristic of the specimens from Elba. They occur spread in a layer over the surface of a much decomposed rock, which is probably a rhyolite.

A few of the best crystals were selected for measurement on a Goldschmidt two-circle reflecting goniometer. Some of

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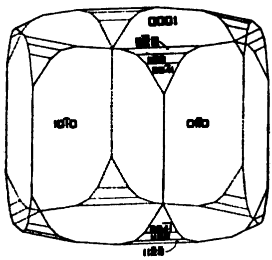

them showed combinations of the prism $\{10\bar{1}0\}$ and base $\{0001\}$, while others presented in addition to these forms several pyramids of the second order. In all cases, however, the most prominent forms were the prism $\{10\bar{1}0\}$ and the base $\{0001\}$. These faces ordinarily play a very subordinate part in the crystallization of hematite and by their prominence here we obtain a distinct prismatic crystal habit hitherto rarely recorded for hematite. The results of the measurements on two crystals are given in detail and along with them, for purposes of comparison, the calculated results for the symbols deduced. If we consider the pyramids as of the second order then the prism becomes the prism of the first order. All the forms observed here are already well known, the complete list being as follows:—$\{0001\}$, $\{10\bar{1}0\}$, $\{11\bar{2}8\}$, $\{11\bar{2}2\}$, $\{22\bar{4}1\}$.

CRYSTAL No. I.

No.	Measured. ρ	Measured. ϕ	Calculated. ρ	Calculated. ϕ	Symbol.
1	0°	....	0°	....	$\{0001\}$
2	90°	0° 15′	90°	0°	
3	90°	0° 2′	90°	0°	
4	90°	0° 8′	90°	0°	
5	90°	0° 15′	90°	0°	$\{10\bar{1}0\}$
6	90°	0° 10′	90°	0°	
7	90°	0° 8′	90°	0°	
8	72° 21′	29° 52′	72° 22′	30°	$\{22\bar{4}1\}$
9	38° 36′	28° 2′	38° 11′	30°	
10	37° 15′	27° 46′	38° 11′	30°	
11	38° 24′	30° 25′	38° 11′	30°	$\{11\bar{2}2\}$
12	37° 15′	30° 40′	38° 11′	30°	
13	40° 6′	28° 55′	38° 11′	30°	

CRYSTAL No. II.

No.	Measured. ρ	Measured. ϕ	Calculated. ρ	Calculated. ϕ	Symbol.
1	0°	....	0°	....	$\{0001\}$
2	90°	0° 14′	90°	0°	
3	90°	0° 2′	90°	0°	
4	90°	0° 17′	90°	0°	$\{10\bar{1}0\}$
5	90°	0° 3′	90°	0°	
6	90°	0° 1′	90°	0°	
7	72° 22′	29° 31′	72° 22′	30°	$\{22\bar{4}1\}$
8	72° 22′	29° 45′	72° 22′	30°	
9	12° 30′	29° 45′	11° 7′	30°	$\{11\bar{2}8\}$

The accompanying drawing, fig. 1, was prepared from a gnomonic projection showing the projection points of the normals of an idealized crystal representing all the forms obtained. The relative central distance for the different forms indicated in the drawing corresponds very closely with that of the crystals examined.

Hematite crystals showing the prismatic habit have been described by Pirsson.* His specimens were also obtained from Mexico and were peculiar in their association with cassiterite, which was frequently contained in the hematite as inclusions. Some of the Guanajuato crystals were finely powdered and treated with hot concentrated hydrochloric acid; the resulting solution was tested in the usual method and was found to be free from tin.

These observations were made in the Mineralogical Laboratory of the University of Toronto.

* This Journal, vol. xlii, pp. 407, 1891.

Department of Mineralogy, University of Toronto,
December, 1903.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *An Attempt at a Chemical Conception of the Universal Ether.*—D. J. Mendeléeff, the celebrated author of the Periodic System of the Elements, has published some speculations in regard to the ether.

From a realistic standpoint it is inevitable that weight and chemical individuality should be ascribed to the ether. It must be a distinct chemical substance so light that it can escape the attraction of the fixed stars by the swiftness of the motion of its molecule; it can have no chemical affinity; its power of diffusion must be so great that it can penetrate all bodies, and thus elude being weighed, although it actually possesses a very minute weight. It can be assumed to be an inactive gas of the argon-helium series with very small atomic weight. By means of *inter*polation the author has predicted new elements (scandium, gallium, and germanium), and he ventures to make *extra*polations below helium. In the place before hydrogen he assumes the existence of an inactive element, which possibly is identical with *coronium*, with an atomic weight estimated at about 0·4. The ether must have a still smaller atomic weight, the value of which, $<0{\cdot}17$, on account of the double extrapolation, is very uncertain. For the ether as an element the author proposes preliminarily the name *Newtonium*. He calculates also, that, in order that it might escape from the largest bodies of the universe, the atomic weight of the ether might necessarily be as small as one-millionth of that of hydrogen.

The author gives, in addition, a realistic explanation of radio-activity by supposing that the radio-active elements (U, Th, Ra) on account of their abnormally high atomic weights are capable of holding a relatively large number of the ether atoms about their large centers of mass, without combining with them chemically, and that the arrival and departure of the ether molecules is accompanied by disturbances in the ethereal medium which produce the rays of light.—*From an abstract in Chem. Central-Blatt*, 1904, i, 137. H. L. W.

2. *Gold Fluoride.*—Since gold frequently accompanies fluor-spar in natural deposits, it seemed possible that gold fluoride might play a part in the formation of such deposits. Therefore, Victor Lenher has undertaken a study of the relations of gold and fluorine. Finely divided oxide of gold was found to be entirely unattacked by hydrofluoric acid, even in the presence of nitric acid. It was found to be impossible to prepare gold fluoride by the interaction of silver fluoride and gold chloride, for the substances reacted as follows:

$$AuCl_3 + 3AgF + 3H_2O = 3AgCl + Au(OH)_3 + 3HF.$$

Since it seemed that water decomposed gold fluoride as soon as it was formed, attempts were then made to carry out the same reaction in the presence of anhydrous solvents, such as ether, chloroform, carbon tetrachloride, etc., but the substances under experiment were either insoluble in these solvents, or were decomposed by them, so that this method did not succeed. Gold fluoride appears, therefore, incapable of being formed by ordinary reactions, although Moissan, by the action of fluorine gas upon gold at a red heat, obtained a yellow, hygroscopic substance which easily decomposed into the metal and fluorine. It is remarkable that fluorine, the most active of all the elements, should have so slight an affinity for gold.—*Jour. Amer. Chem. Soc.*, xxv, 1136.

H. L. W.

3. *The Separation of Radium from Barium.*—Heretofore the only available method for obtaining products richer in radium from mixtures of barium and radium salts, has been the fractional crystallization of the chlorides or the bromides. MARCKWALD has now found that it is possible to obtain an enrichment in radium by agitating a concentrated solution of the salts with one-fifth of its weight of one per cent sodium amalgam. Barium and radium amalgam is thus formed in which the proportion of radium is much increased over that in the original mixture. By repeating the operation with the residual liquid, after it has been previously neutralized, successive products are obtained which gradually diminish in activity. The method as thus employed offers no advantages over the method of fractional crystallization, since it also is a fractionating process, but it is interesting in showing for the first time a difference in chemical behavior between barium and radium.—*Berichte*, xxxvii, 88. H. L. W.

4. *The Dissociation of the Alkaline Carbonates.* — Having previously shown that lithium carbonate can be completely volatilized in a vacuum above 1000° in consequence of its dissociation into carbon dioxide and lithium oxide, P. LEBEAU has studied the behavior of the carbonates of sodium, potassium, rubidium and cæsium under the same conditions. He has found that all of these carbonates are dissociated above 800° with the formation of carbon dioxide and a volatile alkaline oxide, so that a sort of volatilization of the carbonates takes place. When the alkali metals are divided into two sub-groups, lithium and sodium comprising the first, and potassium, rubidium and cæsium the second, it found that the ease of dissociation decreases with the atomic weight in the first sub-group, and increases with it in the second. —*Comptes Rendus*, cxxxvii, 1255. H. L. W.

5. *Combination of Saccharose with Certain Metallic Salts.*— It is known that cane-sugar unites with sodium chloride, bromide and iodide, as well as with potassium chloride, to form crystalline compounds. D. GAUTHIER has recently succeeded in obtaining a number of other similar compounds which are well-defined. The following substances are described :

$C_{12}H_{22}O_{11}\cdot KI\cdot 2H_2O$
$C_{12}H_{22}O_{11}\cdot LiCl\cdot 2H_2O$
$C_{12}H_{22}O_{11}\cdot LiBr\cdot 2H_2O$
$C_{12}H_{22}O_{11}\cdot LiI\cdot 2H_2O$
$C_{12}H_{22}O_{11}\cdot CaBr_2\cdot 3H_2O$
$C_{12}H_{22}O_{11}\cdot CaI_2\cdot 3H_2O$
$2C_{12}H_{22}O_{11}\cdot BaCl_2$
$2C_{12}H_{22}O_{11}\cdot BaBr_2$
$2C_{12}H_{22}O_{11}\cdot BaI_2$

It is proposed to study the properties of these bodies in the future, and also to attempt the preparation of compounds with other salts.—*Comptes Rendus*, cxxxvii, 1259. H. L. W.

6. *The Density of Chlorine.*—New determinations of the density of chlorine gas have been made by MOISSAN and JASSONEIX. The method of Dumas was employed, which consists in filling a globe having a slender neck with the gas, by displacement, sealing the neck by fusion, and weighing. Considerable difficulty was experienced in obtaining pure chlorine; even liquid chlorine was found to hold other gases in solution, and the best results appear to have been obtained by using chlorine which had been previously solidified by cooling. As an average of the best results, the density 2·490 at 0° is given. This number agrees very closely with Leduc's result, 2·491, published in 1897.—*Comptes Rendus*, cxxxvi, 1198. H. L. W.

7. *The Doppler Effect in Electrical Sparks.*—If metallic particles are torn off from the electrodes between which a spark is produced and are lighted, one would expect on looking in the direction of the spark with a suitable optical arrangement to see, according to Doppler's principle, a displacement of the lines of the spectrum. AUG. HAGENBACH uses two sparks in front of the slit of a spectroscope. The current was directed through these gaps in opposite directions. In one experiment Michelson's echelon spectroscope was used with mercury lines. The results were negative; and the author concludes that there is no displacements greater than 0·01 A.-unit; if the Doppler principle holds for the case of electric sparks, the velocity of the metallic particles cannot be greater than this value indicates. In another experiment a Rowland grating was used and a similar result was reached. The author's results do not agree with those obtained by Schuster and Hemsalech, or with those of Mohler, in regard to the velocity of the shot off particles. These authors found a large velocity for such particles.—*Ann der Physik*, xiii, pp. 362–374. J. T.

8. *Effect of Temperature on Ionization by Röntgen Rays.*—R. K. MCCLUNG, working in the Cavendish laboratory, believes that he has proved conclusively that, in a given volume of gas, kept at a constant density, the amount of ionization produced by Röntgen rays of a given intensity is independent of the temperature of the gas.—*Phil. Mag.*, 1904, pp. 81–95. J. T.

9. *The Arc in Metallic Vapors in an Exhausted Space.* —Dr. E. Weintraub has conducted, in the laboratory of the General Electric Company at Schenectady, an exhaustive series of experiment on the Cooper-Hewitt mercury lamp.

(1) By a series of experiments it was shown that in the process of starting an arc the cathode plays an important role, so that a certain change must take place on its surface before the arc can start; the anode receives the current without any previous excitation.

(2) Starting from the recognition of this role of the cathode, a new method has been devised for an instantaneous starting of the passage of a moderate voltage current through the space separating the electrodes, and this no matter how long this space is.

(3) The properties of the mercury arc have been studied, and a number of differences in the behavior of the cathode and the anode, beside the one mentioned above, stated.

(4) The behavior of amalgams, as well as pure alkali metals, has been investigated, and the complete analogy between the behavior of the arc in their vapors and that of the mercury arc shown.

(5) Different ways have been found to cause an alternating current to pass through mercury vapor in form of an arc.

(6) On the basis of this a theoretically almost perfect rectifier for conversion of alternating current into steady direct current was developed.—*Phil. Mag.*, Feb., 1904, pp. 95–124. J. T.

10. *Electricity and Magnetism. An Elementary Text-Book Theoretical and Practical;* by R. T. Glazebrook. Pp. viii + 440. Cambridge, 1903 (The University Press).—This volume, like the others by the same author in the Cambridge Physical series, is based on the first year work in physics as given at the Cavendish laboratory. Also, like its predecessors, it is a type of text-book little used in this country. The ordinary method of carrying on instruction in physics is threefold; first, by means of a lecture course, second, by laboratory work, and third, by a quiz. As an aid to the two latter branches, the common practice in this country is to provide the student with two separate text-books—one treating the theory of the subject from a general standpoint and the other containing directions more or less minute for a certain number of experiments. On the other hand, the English practice, as exemplified in the book before us, is to combine the two books into one. That this method has certain advantages in giving the student a better perspective is obvious; and that this view is coming to be more appreciated here, is evidenced by the volume on Mechanics and Heat which has recently appeared from the Ryerson laboratory at Chicago. (See below.)

The development of the doctrines of electricity and magnetism, together with their more important applications, is carried out admirably along the lines which Maxwell made classic. The experiments are well chosen and numerous examples are scattered

through the book to aid in driving the principles home. The most recent developments in the science also receive adequate attention, the last two chapters being on Hertzian waves and the recent work on the discharge through gases. The demonstrations and deductions are often of the unsatisfactory nature which the necessity of excluding the Calculus makes unavoidable. But aside from this defect, which is inherent in any presentation written for students in a like state of mathematical ignorance, this book appears to the writer to be the most satisfactory one that has come under his notice. L. P. W.

11. *Mechanics, Molecular Physics and Heat.* A Twelve Weeks' College Course; by R. A. MILLIKAN. Pp. 242. New York, 1903 (Ginn & Co.).—This book is a combined text-book and laboratory manual. It represents an attempt to attain a closer coördination between the laboratory, the class room, and the lecture room, and as such is to be highly commended. No one who has taught elementary Physics can fail to be in sympathy with this aim or to be interested in the way in which the problem is attacked in the Ryerson Laboratory. The writer can recommend the preface of this book to all who are interested in the very serious problem of how best to teach Physics.

Judging from personal experience with students of the maturity implied, it would seem as if too much knowledge were assumed. Neither velocity nor mass are explicitly defined. The logical sequence of the development of the principles of mechanics is not all that could be desired. On the other hand, the selection and arrangement of the experiments and problems is excellent. On the whole it would seem that while the book is well adapted to the system of instruction in use at Chicago, its usefulness elsewhere will be limited—unless that system comes to be generally adopted. L. P. W.

12. *Treatise on Thermodynamics;* by MAX PLANCK. Translated by ALEXANDER OGG. Pp.xii + 272. New York (Longmans, Green & Co.).—This is an excellent translation of Professor Planck's well-known work on thermodynamics which appeared in 1897, embodying in a connected treatment of the subject the author's many original contributions to this branch of science. Like all of Planck's work, it is marked by strict and satisfactory logical development and by a clear recognition of the nature, authority and limitations of our knowledge of the general principles upon which the science is based. The treatment of the Second Law, while essentially the same as that employed by Clausius, Kelvin and Maxwell, is, at the same time, original in its point of view and is very illuminating; it should not be neglected by any serious student of thermodynamics. Irreversible processes receive a larger share of attention than is usual—a most commendable feature in a text-book since all actual thermodynamic processes are irreversible, and it is, therefore, very essential that the knowledge of the working physicist and engineer should not be confined to the ideal reversible case. The book also gives a large amount of space to the discussion of the applications of thermodynamics to the problems of chemical equilibrium and it should

be very useful to the student of physical chemistry. From the pedagogical point of view, one could wish that the author had not confined himself so strictly to analytical methods and that more diagrams and geometrical illustrations had been employed; but after all this is largely a question of taste. H. A. B.

II. Geology.

1. *The Coral Reefs of the Maldives;* by Alexander Agassiz. Mem. Mus. Comp. Zool. Harvard College. Pp. i–xxv, 1–168, 82 pls. One volume text. One volume plates.—Parts of December, 1901, and January, 1902, was spent by Professor Agassiz in exploring the Maldives (for sketch of the work of this expedition see this Journal, xiii, 297). All of the important atolls were examined and more than eighty soundings were taken. The variety exhibited by the small islands points "to the uselessness of our present definition of atolls. There is every possible gradation between a curved crescent-shaped open bank of greater or less size and an absolutely closed ring of land surrounding a lagoon without direct communication with the sea. The evidence . . . shows that reef corals will grow upon any foundation where they find the proper depth and that local conditions will determine their existence as fringing reefs, barrier reefs or atolls." In most particulars the work of Gardiner is substantiated (this Journal, xvi, 203), but the soundings reveal considerable irregularity in the depth of the plateau, and the conclusions drawn by Gardiner from the supposed existence of a great level central plateau may need revision. The soundings show also that Darwin's suggestion that the Maldive Archipelago originally existed as a barrier reef of nearly the same dimensions as that of New Caledonia, is not borne out.

This is the last of a series of monographs on Coral Reefs, but Professor Agassiz promises a *résumé* of results obtained from study of all the important coral regions of the Atlantic, Pacific and Indian Oceans.

2. *Note on the Classification of the Carboniferous formation of Kansas;* by Henry S. Williams. (Communicated.)—In the brief review of Bulletin 211 of the U. S. Geological Survey (this Journal, xvii, 175), a few facts were not given which perhaps should be stated in order to give credit where credit is due, and the quotation on p. 176 is by its incompleteness somewhat misleading, hence the following statement:

A further examination of Bulletin No. 211 of the United States Geological Survey shows that the following formations, viz: Elmdale, Neva, Eskridge, Garrison, Matfield, and Doyle had previously been given these names by Prosser and Beede and were more fully described by Prosser. Their description was published by Prosser in the Journal of Geology, vol. x, pp. 708–715, which number appeared during the first week of December, 1902, eleven months before the publication of Bulletin No. 211.

Mr. Girty stated that "the evolution of the latest from the

earliest faunas in the section" is shown "to have been a progression from a brachiopod to a pelecypod facies. The gradual character of this replacement has been remarked by most paleontologists who have studied the faunal succession. It is without marked interruption at any point, so that subdivisions appropriate for recognition are not clearly apparent, and there is room for differences of opinion as to where delimitation should be made."

3. *Einführung in die Paläontologie;* von Dr. GUSTAV STEINMANN. Pp. 1–466, figs. 1–818. Leipzig, 1903 (Wilhelm Engelmann).—This elementary treatise on paleontology is written by one of the authors of the "Elemente der Paläontologie" of Steinmann and Döderlein published in 1890, and appears to be an abbreviation and revision of that work, using the same illustrations, with an addition of fifty pages on fossil plants, and numerous new figures. The reduction of a work attempting to introduce the reader to a knowledge of plants and animals of past geological time to 466 pages, makes it necessary to mention only the more conspicuous families, while for each family only the more characteristic are named and very brief descriptions given. It is too technical for general reading and not complete or full enough to be of much use in the laboratory, but it may serve as a means of gaining a superficial knowledge of the names of the more conspicuous genera met with in treatises on geology and thus be of use to the geologist or general student as a means of gaining definite ideas of the forms of fossils. It is well printed and the illustrations are chosen to give a comprehensive idea of the diagnostic characters of the forms illustrated. H. S. W.

4. *The Structure of the Piedmont Plateau as shown in Maryland;* by EDWARD BENNETT MATHEWS.—Attention is called to the fact that fig. 1, p. 150, in the article by E. B. Mathews, is printed in inverted position. The figure is here repeated inserted in its correct position.

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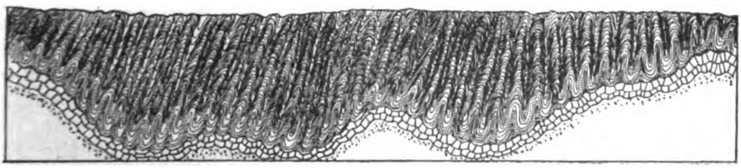

5. *Western Australia Geological Survey.* — Three bulletins have recently been issued as follows:

No. 8. Lennonville, Mount Magnet, and Boogardie, Murchison Goldfield; by CHAS. G. GIBSON. 33 pp. with map.

No. 9. Geological Features and Mineral Resources of Northampton; by A. GIBB MAITLAND. 28 pp. with map and sections.

No. 10. Descriptions of Carboniferous fossils from the Gascoyne District, Western Australia; by R. ETHERIDGE, JR., 41 pp. 6 pls.

6. *The Evolution of Earth Structure;* by T. MELLARD READE. 342 pp., 40 pls., 1903. (Longmans, Green & Co.)—In this volume Mr. Reade has brought together his views upon the causes of crustal movements. The volume falls naturally into two divisions, first the causes of broad vertical movements without tangential thrust, commonly known as epeirogenic; and secondly, the causes of tangential thrusts and their relations to mountain building.

However much geologists may differ from some of the conclusions of the work, the author's method must be regarded as admirable, first presenting generally conceded facts, secondly, framing a hypothesis and, thirdly, showing its mechanical possibility. Thus it may be said that Mr. Reade has developed true causes, but it remains to be seen from further study and generalizations if they are quantitatively sufficient, or if there are other more potent factors. Especially would possible changes of view upon the nature of the earth's interior modify his conclusions.

Taking up the first division of the volume, that concerning vertical crustal movements, Reade cites familiar examples of coastal oscillations and shows the incompetence of the principle of isostacy to initiate such movements or to give them an oscillatory character. The author maintains that isostatic equilibrium is true as a broad principle, as shown by the fact of the specific gravity of the continental crust and subcrust being less than that beneath the oceans, but relates this to diastrophic movements by assuming that slight regional changes of volume but not of mass occur deep within the earth.

Lateral shiftings within the earth would also result in such movements, but no cause has been shown why within a solid earth matter should so shift, especially as work would be done in lifting the continental masses. In favor of the view that the movements are due to slight volume changes without changes of mass or lateral shifting, Reade discusses the irregular changes of density which take place during the cooling of a bar of iron and the change in density due to magnetization.

The author believes that most of the fluctuations of volume take place within a depth of 500 miles from the surface in what he terms the "sphere of igneous magma" and "the condition of the matter may be normally solid, but potentially fluid, or actually fluid when nearing the surface." Following this statement of causes, the view is expressed from a consideration of the sea coasts that the continents as a whole are at present in an era of low level. An examination of the infrequency of deep sea soundings and the discovery of occasional rapid variations in depth leads to the further conclusion that there is merely negative evidence for the prevalent belief in the smoothness of the ocean floor and the permanence of continents, but that in regions removed from rapid sedimentation more careful soundings may reveal bottoms which still show forms of subaerial erosion. A considerable degree of impermanence of continents is further shown by a consideration of basins of sedimentation, and as bearing upon this problem two previous papers, "Denudation of the Two

Americas" and "The North Atlantic as a Geological Basin" are reprinted.

Turning to the author's views on orogeny, the belief is expressed that periods of mountain-making are related to the formation of new land areas, the orogenic cause consisting in alternate expansions and contractions, and being essentially that developed in his volume "The Origin of Mountain Ranges," 1886. Further details are added, however, giving the results of laboratory experiments upon models of various forms. These show how with circumferential compression strata may be folded into parallel crescentic or radiating crescentic folds with minimum mass deformation of the beds. The resulting forms are developable surfaces, made by simple bendings of the strata. An initial bias is shown to be an important factor in determining the form of yielding, and the whole is an important contribution showing the effects of compression acting in two or more directions simultaneously.

While Reade has demonstrated the adequacy of repeated expansions and contractions in producing deformations in several substances, notably to the distortions of a lead-lined sink, to the reviewer's mind it is far from being demonstrated quantitatively sufficient to result in mountain-making, chief among the objections being first, that there is no evidence of the numerous widespread fluctuations of internal temperature which would be necessary for the amount of shortening shown in the chief mountain ranges; secondly, that the unequal heating of higher and lower beds would result in differential movement and friction in transmitting the thrust to a distance, lessening the effective thrust of the expanding stratum and tending to produce local vertical mass deformation rather than distant folds. Thirdly, this theory does not account for the deferment of mountain-making for millions of years, during which time progressive sedimentation and subsidence is going forward, followed by a relatively brief epoch of crustal yielding.

In the latter part of the book the author devotes two chapters to faulting and to slaty cleavage. J. B.

III. Miscellaneous Scientific Intelligence.

1. *Smithsonian Institution*, S. P. Langley, Secretary, *Report for year ending June 30, 1903.*—The annual report of the Smithsonian Institution gives a summary of the work done in the several fields of activity. In the appendixes to the general report are more detailed statements regarding work of the National Museum, the Bureau of Ethnology, etc. The Museum is to have a $3,500,000 building in which its large and rapidly increasing collections may be properly stored. The Astrophysical Observatory has made special bolographic studies of the absorption of the solar rays. The atmosphere "has been more opaque than usual within the present calendar year, so much so as to reduce the direct radiation of the sun at the earth's surface by about 10 per cent throughout the whole visible and infra-red spectrum, and by more than double this amount in the blue and

violet portions of the spectrum." A new determination of the temperature of the sun gives 5920° C. For the study of sun spots, a horizontal reflecting telescope of 140 foot focus and 20 inch aperture, provided with a new form of coelostat, has been constructed.

2. *Smithsonian Miscellaneous Collections, Quarterly Issue.* Vol. I, Pts. 1 and 2.—The Quarterly issue of the Smithsonian Miscellaneous Collections is designed to afford a medium for early publication of the results of researches conducted by the Institution and for reports of a preliminary nature. The Quarterly Issue will not supersede but will form part of the regular series of the Smithsonian Miscellaneous Collections. It will be published about the first of January, April, July and October. Each number will consist of about 144 pages and will be suitably illustrated. The present number contains seventeen articles, among them the description of the new telescope and coelostat, by C. G. Abbott, mentioned in Secretary Langley's report (see above).

3. *Weather Bureau, U. S. Department of Agriculture.*—The two following volumes have recently been issued:

Bulletin L. Climatology of California; by Alexander G. McAdie. 261 pp., 31 figs., 12 pls. The great variety of climates existing within California and the numerous abnormalities exhibited, e. g., at San Francisco, makes the description of the meteorological conditions within the State of more than local importance. Professor McAdie discusses the controlling climatic factors of the Pacific Coast region, after which come descriptions of conditions prevailing in different parts of California. The chapter on Fog is particularly valuable, as the conditions at San Francisco are unusually favorable for the study of this phenomenon.

Bulletin No. 33. Weather Folk Lore and Local Weather Signs; by Edward B. Garriott. 183 pp., 21 pls. Many of the everyday sayings regarding weather signs are true and have come from careful observation on the part of sailors, farmers and other men. Many weather proverbs, on the other hand, are ridiculous. Professor Garriott has classified and discussed these sayings and gives the true weather signs for 143 stations within the United States.

4. *Scientia*, No. 22.—The latest addition to this valuable series is entitled: Diagrammes et Surfaces Thermodynamiques, par J. W. Gibbs. The translation was made by M. G. Roy of the University of Dijon and an introduction is given by M. B. Brunhes of the University of Clermont.

Obituary.

Dr. Charles Emerson Beecher, Professor of Paleontology in Yale University, died suddenly of heart failure on February 14, in his 47th year. A biographical notice will appear later.

Professor Karl Alfred von Zittel, the eminent paleontologist of the University of Munich, died on January 6, at the age of 65.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXIII.—*Criteria relating to Massive-Solid Volcanic Eruptions*; by Israel C. Russell.

Since Monte Pelé presented geologists with a marvelous illustration of the ability of a volcano under certain special conditions to force a mighty column of solid lava vertically upward into the air from the summit of its conduit, the question has frequently been asked: Are other examples of a similar nature known? The reply is that no similar shaft of solid rock has been seen to ascend from the summit of a volcano, but evidences of former protrusions of a like nature have been recognized, and as it seems, when search is made aided by the experience recently gained on Martinique,* the records of massive-solid eruptions that have occurred in the past will perhaps be found to be somewhat common.

In order that the appearance of the example of a massive-solid volcanic eruption which will no doubt in the future be taken as the type of its class, may be fresh in mind, the reader should turn to the admirable photographs of the "obelisk" of Monte Pelé, published by Dr. E. O. Hovey, in this Journal, October, 1903.

The striking object lesson furnished by the growth of the obelisk of Pelé has already stimulated geologists to search for the records of similar occurrences in other regions. Results in this direction have been reported by Hovey,† who during a continuation of his important explorations in the Lesser Antilles, found that the Grand Soufrière of Gaudeloupe, and the prominent central peak on the Island of Saba,

* Descriptions and illustrations of the obelisk of Pelé by E. O. Hovey, have been published in this Journal, October, 1903, vol. xvi, pp. 269-281; and in Science for November 13, 1903, vol. xviii, pp. 633-634. These articles contain references to the publications of other observers. See, also, "The Pelé Obelisk," by Israel C. Russell, in Science for December 18, 1903, vol. xviii, pp. 792-795.

† This Journal, vol. xvi, October, 1903, p. 281.

bear evidence of being the result of massive-solid eruptions like that Pelé is now experiencing. "This is especially clear," writes Hovey, "in the case of the Grand Soufrière, the cone of which rises above an old crater-rim which it has buried in the same way that Monte Pelé is now striving to bury its surrounding crater-walls." The details on which this conclusion is based have not yet appeared in print, but will no doubt when published furnish a valuable contribution to the history of volcanoes.

Sir Richard Strachey, in a note in Nature,* presents a sketch, but unfortunately not accompanied by a description, of certain prominent columns in the Deccan trap region of India, which have at least a superficial resemblance to the obelisk of Pelé. The columns represented in the sketch, however, appear to be examples of the nearly complete removal by erosion of remnants of a formerly extensive lava sheet resting on less resistant beds which locally have been left in relief and now appear as buttes or hills owing to the shelter afforded by the hard bed above them. Similar buttes with prominent columns on their summits are well known in the western portion of the United States, and have long been recognized as monuments spared by erosion. This tentative explanation, while based principally on the sketch published by Strachey, and familiarity with similar topographic forms in the region drained by the Columbia River, and occupied by the Columbia River lava—the counterpart in many ways of the Deccan trap of India—is sustained by other considerations, as will appear later in this article.

Professor John C. Branner† has recently invited renewed attention to Fernando de Noronha, an island in the South Atlantic about 230 miles from the northeast coast of Brazil, the summit of which is formed by a conspicuous, irregular tower-like mass of igneous rock, 500 feet high, the inaccessible summit of which rises 1000 feet above the sea. In the article referred to mention is made of the fact that Charles Darwin, in giving an account of his observations while connected with the voyage of the *Beagle* in 1832 to 1836, remarks in reference to the Peak of Fernando de Noronha: "One is inclined to believe that it has been suddenly pushed up in a semi-fluid state." Sketches of the remarkable culminating spire of the island are also presented and its resemblance in form and similarity of position in reference to the elevation on which it stands, to the obelisk of Pelé, pointed out.

Branner states frankly, however, that the resemblance of the Peak to the obelisk of Pelé "may be quite accidental," and in the earlier article mentioned in the preceding footnote presents

* Vol. lxviii, Oct. 15, 1903, pp. 573–574.

† This Journal, December, 1903, Series IV, vol. xvi, pp. 442–444. A detailed account of the geology of Fernando de Noronha, also by Branner, was published in the same Journal, Series III, vol. xxxvii, 1889, pp. 145–161.

evidence tending to show that, as suggested by Darwin, "the Peak is part of a great dike, the only remnants of which now exposed are the upper portions of the Peak itself, and the columns at the Horta do Pico, a short distance to the south-west."

In the case of the buttes of the Deccan trap region of India, and of the Peak of Fernando de Noronha, the suggestions that have been offered in reference to their being of the same type as the obelisk of Pelé, are based almost entirely on similarity of form; but something more than this is evidently required before similarity of origin can be considered as established. In the study of topographic forms of the nature of those in question, it is essential that criteria for their classification should be formulated. An attempt in this direction will be made later in this article, after which the places to be assigned the monumental forms brought to the front by Strachey and Branner will be considered.

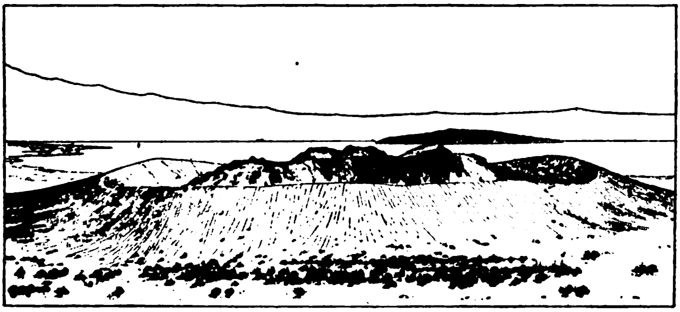

FIG. 1. Panum Crater, Mono Lake, California.
(Reproduced from the Eighth Annual Report of the U. S. Geological Survey.)

It is not necessary to go to India and Brazil, however, to find illustrations of massive-solid volcanic eruptions of the Pelé type, as instructive examples occur among the abundant volcanic records of the United States.

In the case of the extensive group of recent volcanic craters on the east side of Mono Lake, California, there are several examples of the upward protrusion of highly viscous or essentially solid lava which, in at least one instance, rose in a tower-like form to a greater height than the rim of the crater of lapilli which surrounds it. The phenomenon referred to is described as follows in my book entitled "Volcanoes of North America,"* in which the above sketch of Panum crater also appears:

* Israel C. Russell: "Volcanoes of North America." The Macmillan Company, New York, 1897, p. 221. The account of the Mono Craters presented in this book is based on an earlier publication by the same author; namely, "Quaternary History of Mono Valley, California," in the 8th Annual Report of the U. S. Geological Survey, Washington, 1889, pp. 378–386.

"In some cases when an upwelling of lava occurred [in the Mono Craters] it barely entered the bottom of the bowl of lapilli before becoming congealed. The eruption then ceased, so far as that individual vent was concerned. At other times, the thick viscid lava was forced up in the center of the crater until it stood higher than the encircling rim of lapilli, but did not expand laterally. In instances of this nature there is a deep, moat-like depression between the rough and angular protrusion of lava and the smooth inner slope of the encircling crater, in which we may walk entirely around the central tower-like mass. The type of this variety of eruption is furnished by the crater shown in the following illustration [here reproduced] which stands near the shore of Mono Lake, and has been named Panum crater."

The tower-like mass of lava in Panum Crater is not of the nature of a cone of eruption, as is explained in the monograph on Mono Valley referred to above, but a protrusion of angular, massive rhyolitic lava the chemical composition of which is given later in this essay. The lava at the time of its extrusion was so nearly solid that it rose with essentially vertical wall to a height of about 150 feet without exhibiting a tendency to flow in any direction. In the light of the recent example furnished by Pelé, this protrusion of lava may be accepted as being of the nature of a massive-solid eruption, which occurred subsequent to the explosive eruptions that built the sharp-crested encircling crater of lapilli.

The observations pertaining to a peculiar volcanic eruption which occurred in Bering Sea in 1883, during which the shape of Bogosloff Island was greatly altered, are discussed in "Volcanoes of North America," referred to above, and the following conclusion as to its general nature presented:

"Although not personally familiar with Bogosloff, I venture to suggest, from what I have seen in connection with other volcanoes, that the formation of the island was due to the outwelling of viscous lava, which hardened at the surfaces so as to resemble the rough, scoriaceous surfaces so common in lava flows. The lava, being quickly cooled, did not flow as a stream, but as in the case of some of the Mono craters previously described, rose in rugged scoriaceous masses, without much explosive violence. Nothing resembling a crater ring of lapilli and dust is reported as surrounding the elevated crags of lava."

Here again the evidence, interpreted with the aid of the more typical example furnished by Pelé, indicates that a massive-solid eruption occurred. In this instance, the volcanic conduit opened beneath the sea, and the eruption was subaqueous, but a protrusion of essentially solid lava took place, the summit of which rose to a height of 325 feet above the

ocean's surface, and, as is shown by a sketch* made in the fall of 1883, here reproduced, had a tower-like form similar to the obelisk of Pelé.

The rock of which Bogosloff is composed, as determined by G. P. Merrill,† is hornblende-andesite, an analysis of which is presented in the table on page 261 of this essay.

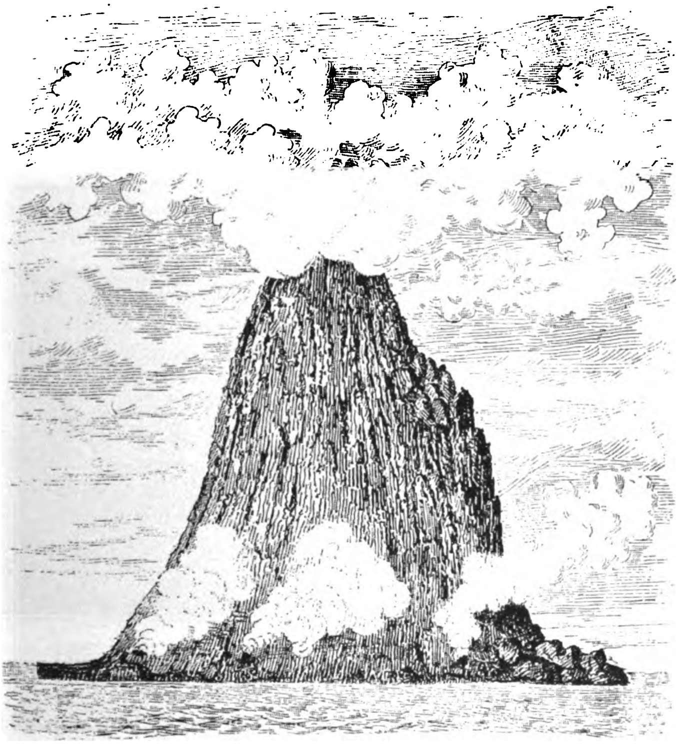

Fig. 2. The New Volcanic Island of Bogosloff, as seen September-October, 1883. After W. H. Dall.

In the case of Bogosloff, there is no evidence on record of a lava flow, or that any of the material extruded was in a fluid or even moderately plastic condition. As will be remembered, no fluid lava was discharged from Panum Crater, and up to the present time during the still continuing period of activity of Pelé only fragmental-solid and massive-solid eruptions have occurred, excepting that highly viscous clots which fell as

* Science, vol. iii, 1884, p. 285.

† Science, vol. iv, 1884, p. 524; also Rocks, Rock-Weathering and Soils, by the same author. The Macmillan Company, New York, 1897, p. 84.

"bread-crust bombs" were thrown out. It is of interest to add to this short list of volcanoes which have erupted material in a massive-solid condition, another example, from which lava was discharged in the three or four ways illustrated by Pelé, and also gave origin to a stream of lava.

The volcano referred to is one of five of modern date (post-Glacial) situated on the east border of Pauline Lake in the south-central part of Oregon, which was visited by the writer during the summer of 1902. A view of the interior of the crater, showing a rough but generally level surface surrounding

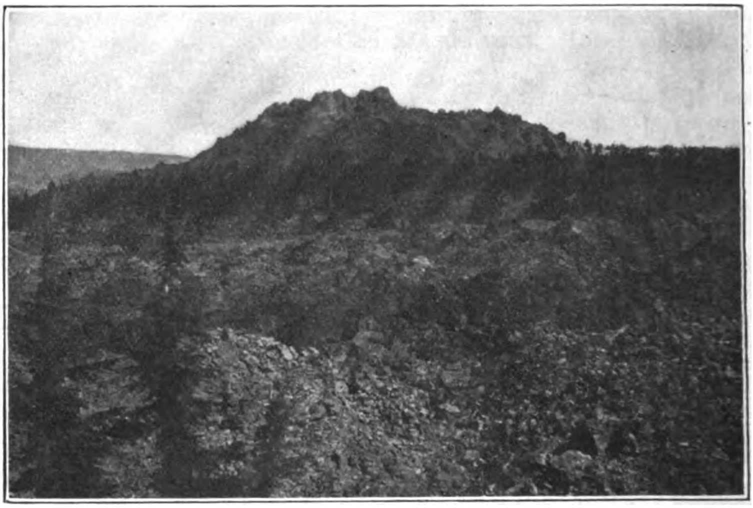

FIG. 3. Crater of a volcano near Pauline Lake, Oregon, with massive-solid extrusion in its center.

a central mass of crags, is here presented. The rim of the crater, not appearing in the illustration, is composed mainly of light-colored pumiceous lapilli, and is still intact for about three-fourths of its original circumference, but its northern portion is concealed, or more probably was breached and carried away by a lava flow which was discharged from the crater and went northward for a distance of two miles, and expanded to a width of about one mile. All of the material extruded seems to be andesite, which ranges in physical characteristics from compact, dense, black volcanic glass or obsidian, to yellowish-white pumice so light that it will float on water with the buoyancy of cork. The lava stream has an excessively rough surface, consisting of blocks of obsidian of all sizes up to eight or ten or more feet in diameter with sharp edges and corners, which form irregular piles and ridges in many instances fifty

or more feet high, as well as massive escarpments and smooth fissure-walls of the same material. In many places the glass passes into a highly scoriaceous rock, resembling a coarse black pumice. Along the sides and at the distal end of the lava stream it terminates in precipitous escarpments, exceedingly difficult to climb, from 50 to 80 feet high. The slope down which the lava flowed has a descent by estimate of at least 500 feet to a mile, and the fact that the stream halted on such an incline and cooled with essentially vertical borders, shows that it was excessively viscous at the time it was spread out.

The feature of chief interest in connection with the volcano in question is a tower-like mass of crags of gray stony or granular homogeneous augite-andesite (as determined by F. C. Calkins, of the U. S. Geological Survey), without either obsidian or scoria and in which there is a notable absence of a "flow-structure," which rises to a height of about 250 feet above the crater's floor. The sides of the central mass of crags, as may be judged from the accompanying photograph, are precipitous, and allowing for the blocks that have fallen, must at one time have been nearly vertical. The lava of which the crags are composed is fresh in appearance, there being no discoloration of the surface, and scarcely a lichen has taken root upon it. It exhibits no evidence of there having been a tendency to flow laterally at the time it was upraised, and although irregularly jointed is not columnar.

A peculiar feature of the floor of the crater at the base of the crags described above is that the lapilli, of which it is composed, are in irregular heaps and piles with steep-sided depressions between, the variations in height between the hills and hollows being from 10 to fully 30 feet. The topography of this surface is surprisingly like that of certain glacial moraines, but its roughness is due in part to the occurrence, at a late stage in the activity of the volcano, of many mild steam explosions in the fragmental material of which it is superficially composed, and in part to the formation of fissures in the rocks beneath, which permitted the loose material resting on them to subside irregularly. About the outer margin of the floor of the crater from its eastern around its southern to its northwest portion, there is a belt about 150 feet wide composed of obsidian and black scoria, which resembles the surface of the associated lava flow. This partially encircling belt of large fragments margining the crater's bottom is due to motion which took place after the lava of which it is composed became solid, but whether the motion was of the nature of an underflow in still viscous material beneath a rigid crust, or was an upward movement of the entire lava column within the crater, is uncertain. I am inclined, however, to the latter opinion.

Without attempting to put on record at this time all of the instructive features of the volcano on the border of Pauline Lake, the facts in its history of chief interest in connection with the study of massive-solid eruptions may be briefly enumerated as follows:

The beginning of the eruption was characterized by the occurrence of violent steam explosions, which blew away the highly scoriaceous summit portion of the column of molten material that rose in the conduit of the volcano; the material thus extruded consists mostly of light colored pumice, but mingled with it are sharp-edged flakes of obsidian, and fell about the opening from which it came so as to build a well defined, sharp-crested crater with smooth slopes. The product of these earlier explosions, together with the similar material blown out at about the same time from four associated volcanoes of the same character, was distributed widely over the adjacent mountains. Succeeding the earlier and most violent explosions, came an outwelling of viscous lava which flowed northward down a moderately steep incline, but did not spread widely and was so thick and viscous that it came to rest with nearly vertical borders, the slopes of which have since been reduced by the shattering of the glass of which they are composed, and the fall of the fragments so as to make steep talus aprons. After the discharge of viscous lava, the central portion of the ascending lava column became rigid and was forced upward by pressure from below until it stood, as at present, in massive crags, 250 feet high. Changes of temperature have caused some shattering of the central mass of stony andesite, but not nearly so much as in the case of the surface of the neighboring obsidian lava-flow. Following or accompanying the protrusion of the central crags, renewed but minor explosions occurred about its base, during which the rocks involved were broken and tossed about but not thrown to a great height or widely distributed. Mingled with the angular fragments now occupying the larger portion of the crater and filling it nearly to the level of the part of its encircling rim which remains, there is an occasional volcanic bomb. These bombs have something of the characteristic football shape common among such volcanic products. The examples seen are about eight inches in diameter, and do not show a "bread-crust" or other conspicuous surface features. These masses were projected into the air during explosions in a viscous condition, and received their rudely spherical shapes owing to rotation about their longer axes during their ærial flights. They cooled before striking the ground and were not flattened, and were not sufficiently plastic to adhere to the loose stones on which they fell. Following the period of mild,

superficial explosions came movements which broke the rocks on which rests the irregular surface covering within the crater, and apparently an ascent through a distance of a few feet of nearly its entire mass.

The short list given on the preceding pages, namely, certain of the Mono Craters, Bogosloff, and the nameless crater in Oregon just described, contains all the known or reasonably inferred examples of massive-solid volcanic eruptions in America, which can be referred to the Pelé type.

With the fresh impetus to the study of volcanoes supplied by the remarkable behavior of Pelé, a demand has been made manifest for criteria by means of which the topographic forms produced by massive-solid eruptions can be distinguished from analogous features in the relief of the land. The first step in this direction is the formulation from all available data, aided by reasonable inferences, of a mental conception of the topographic and other characteristics that massive-solid eruptions should present. The facts in hand are sufficient to enable one to make an approximation to such a conception, but the picture will no doubt have to be modified as investigation progresses.

TABLE OF ANALYSES.

Constituents.	No. 1. Rhyolite.* Mono Lake.	No. 2. Hypersthene† Andesite. Monte Pelé.	No. 3. Hornblende Andesite.‡ Bogosloff.	No. 4. Phonolite.§	No. 5. Basalt. Cinder Buttes. ‖
SiO_2	74·05%	61·44%	56·07%	58·02%	51·14%
Al_2O_3	13·85	17·27	19·06	20·03	13·95
Fe_2O_3	trace	2·53	5·39	6·18	2·15
FeO		4·18	0·92		12·97
MgO	0·07	2·28	2·12	0·80	2·21
CaO	0·90	6·36	7·70	1·89	6·56
Na_2O	4·60	3·54	4·52	6·35	3·59
K_2O	4·31	1·49	1·24	6·18	2·33
H_2O	2·20	·88	0·99	1·88	·34

* Analysis by T. M. Chatard, U. S. Geological Survey, 8th Annual Report, 1886–87, Pt. I, p. 380.

† Analysis by W. F. Hillebrand, National Geographic Magazine, vol. xiii, July. 1902, p. 291; average of three analyses; minor ingredients as given in original report are not included.

‡ G. P. Merrill, Rocks, Rock-Weathering and Soils, p. 84.

§ G. P. Merrill, Rocks, Rock-Weathering and Soils, p. 80. Average of six analyses given by Zirkel; includes also MnO, 0·58 per cent.

‖ Analysis by W. F. Hillebrand, U. S. Geological Survey, Bull. 199, p. 87: contains also TiO_2 2·41 per cent; ZiO_2 0·12 per cent; MnO 0·44 per cent; BaO 0·25 per cent; P_2O_5 1·59 per cent; Fl 0·10 per cent; FeS_2 (S = 0·08) 0·15 per cent, and traces of V_2O_3; NiO; SrO; and Cl.

One of the first questions to present itself in searching for criteria by means of which massive-solid can be distinguished from other volcanic eruptions, is: Do the lavas extruded in

that condition have any characteristics in their chemical composition which will serve to differentiate them from other lavas? The reply, so far as it can at present be formulated, must evidently be based on the analyses of the rocks known to have been extruded in a massive-solid condition and a comparison of them with the composition of lavas not known to have been erupted in that manner.

In the above table the available analyses of the examples of massive-solid eruptions described on the preceding pages, have been assembled, together with an analysis of a characteristic phonolite (No. 4) to represent the rock of the Peak of Fernando de Noronha, and also an analysis of basalt (No. 5) which is known to have been erupted in a highly fluid condition.

To the examples of massive-solid eruptions cited in the table, should be added an analysis of the augite-andesite of the crater near Pauline Lake, Oregon, described on a previous page, but this data is not available.

As indicated by laboratory experiments made on the fusibility of shales and clays* similar in chemical composition to the rocks enumerated above, the relative fusing points of such rocks may be roughly or qualitatively expressed by the ratio of the silica and alumina to the iron oxides, magnesia, lime, soda and potash, or the "fluxes" present in them. The rule being that for mixtures of the general nature that lavas present, the higher the ratio of the silica and alumina to the fluxes present, the greater the degree of heat necessary to cause fusion, under laboratory conditions. On arranging the analyses given in the above table, so as to indicate the ratio of acid to basic substances given, we have the following:†

TABLE SHOWING RELATIVE FUSIBILITY.

	$SiO_2 + Al_2O_3$.	"Fluxes."	Ratio of $SiO_2 + Al_2O_3$ to "Fluxes."	Approximate temperature of fusion.‡
1. Rhyolite of Mono Craters	87·90%	9·88%	8·8	3100°F.
2. Andesite of Pelé	78·71	19·88	3·9	
3. Phonolite	78·05	21·40	3·6	2520
4. Andesite of Bogosloff ...	75·13	21·89	3·4	
5. Basalt of Cinder Buttes.	65·09	29·81	2·2	2250

As indicated by the ratios given in the third column of

* H. Ries, Clays and Shales of Michigan, in Geological Survey of Michigan, vol. viii, Part I, 1900.

† This table is only approximately correct since no account is taken of the water present; and in the case of the numbers 2 and 5, no account is taken of the several minor constituents given in the analyses as originally reported.

‡ According to experiments by C. Barus, quoted in J. D. Dana's Manual of Geology, 4th ed. 1895, p. 273.

the table, the rocks are arranged according to their degree of fusibility; the most refractory being the rhyolite, and the most fusible the basalt. The known massive-solid eruptions 1, 2 and 3 are thus shown to consist of refractory lavas. On the other hand, basalt, which so far as known has not been extruded in a massive-solid condition, is more readily fusible, and in the case of the example cited, as recorded elsewhere,* was poured out in a highly fluid condition. From the data in hand it appears, therefore, that one of the characteristics of the rocks known to occur in massive-solid extrusions is their refractory nature. That this is always a characteristic condition, however, cannot as yet be definitely affirmed. Another related condition is the amount of water-vapor present, since aqueo-igneous fusion is known to require much less heat than dry fusion. The bearing of this principle on the occurrence of massive-solid volcanic eruptions, although seemingly of fundamental importance, cannot be discussed at this time. Assuming, however, that the influence of water-vapor on the fusion of acid and basic lavas is the same, it is evident, from the data given above, that the former should occur more commonly than the latter, in massive-solid extrusions.

In addition to the presence of a plug of rigid lava in the summit portion of a volcanic conduit, in order to bring about a massive-solid extrusion, it is evident that there must also be sufficient pressure on the base of the plug to force it out. Such pressure, as we know, is present during the eruptions of many and we presume all volcanoes which discharge lava. The critical or determining conditions, which lead to massive-solid eruptions, seem to be that the lava in the summit portion of a volcano in action shall become solid. The lavas most apt to solidify at such times are evidently those which are refractory and on cooling pass quickly from a fluid to a rigid condition; that is, the lavas rich in silica and alumina and relatively poor in basic substances. Hence as it seems, it is to be expected that massive-solid extrusions will consist of rocks like the rhyolites, trachytes, andesites and phonolites, rather than basalts or still more basic lavas.

Judging from the heated conditions of the material extruded during a massive-solid eruption at the time it rises into the air, and reasoning also from the known variations in the physical and mineralogical features of igneous rocks which depend on the conditions under which they solidify, we should expect the lavas extruded in a massive-solid condition to present at least three leading physical characteristics: they should be (1) compact, or at most but moderately vesicular, and not scoriaceous, (2) granular or perhaps finely crystalline but not glassy, and

* Israel C. Russell, U. S. Geological Survey. Bulletin No. 199, Washington, 1902, p. 88.

without conspicuous crystals, and (3) irregularly jointed but without a well defined columnar-structure. Each of these propositions may for convenience be considered separately :

1. A compact rather than a scoriaceous condition of the lava forced out during massive-solid eruptions is to be expected from the fact that preceding liquid or fragmental-solid discharges would have removed the more thoroughly vapor-charged summit portion of the rising column, while the material at a greater depth, less thoroughly vapor-charged and congealing under pressure, would form a compact lava. Turning to the known examples of massive-solid eruptions available for comparison, we find this conclusion sustained in the case of the central crags in the Oregon crater described above, which consists of compact granular material.

2. A stony or granular texture, without well defined or conspicuous crystals, would be expected because the lava consolidates with comparative rapidity near the summit of the conduit from which it is later extruded, thus not allowing sufficient time for an advanced stage of crystallization. On the other hand, cooling takes place less rapidly than in the surface portion of a lava sheet, and a glassy texture would not be expected. The rock in question should seemingly be intermediate in structure between those which cool slowly, as in intruded sheets and the central parts of thick lava flows, and those which cool so rapidly that a glass (obsidian) results. Although this reasoning seems to be logical, yet, as is well known, crystals are sometimes formed in deep-seated magmas and are carried to the surface when the containing magmas migrate outward and are discharged by volcanoes. This phase of the problem is obscure, and possibly a granular or crypto-crystalline structure may not be an essential characteristic of lava extruded in a massive-solid condition.

Turning again to the known examples, we find the rock composing the crags in Panum crater, and the one in Oregon described above, to be stony in texture, and in the case of the Oregon crater at least, without either porphyritic crystals on the one hand, or obsidian or pumice on the other.

3. Columnar structure in igneous rocks, as is well known, results from slow cooling, and the columns formed under such conditions have their longer axes at right angles to the cooling surfaces. As the material forced out during massive-solid eruptions is still hot when it reaches the air, and as the diameter of such extruded masses, so far as known, is but a few hundred feet, it is to be expected that cooling would progress too rapidly and too irregularly to permit of the formation of systematically arranged joints, and hence, a well-defined columnar structure would be absent. If in large extrusions the rate of cooling did permit of the origin of a columnar structure, the columns

should be best defined in the central part of the mass, and radiate outward from a central vertical axis toward the sides. The most that could seemingly be expected, however, would be irregular and confused jointing without the formation of a columnar structure. Once more checking deductions by observation, we find no evidence of columnar structure in the massive-solid material extruded from either the Panum crater or the crater near Pauline Lake. As to the other examples cited, information in this connection is lacking.

There is one other feature of volcanic rocks which might reasonably be expected to occur in those forced to the surface in a massive-solid condition, namely, a brecciated structure; that is, the presence of angular fragments of the parent lava, adhering one to another or united by portions of the same magma which consolidated about the fragments produced by the fracturing of the portion which cooled earlier. Such volcanic breccias are common in the lava flow about the Mono craters, and in the similar lava stream near Pauline Lake, but have not been observed in the massive-solid extrusion of those localities. From the manner in which massive-solid eruptions take place, however, it seems as if the conditions would favor the production of brecciated rock of the type just mentioned.

The crucial test of the above deductions will come when the activity of Pelé has decreased sufficiently to permit of a critical study of its obelisk. The prediction may be ventured, however, that it will be found to be composed of massive but somewhat porphyritic rock since the products of the fragmental-solid eruption are of this nature, and without definite columnar structure, although irregular or confused jointing will no doubt be present.

In reference to the topographic forms analogous to those produced by massive-solid eruptions and which might be mistaken for them, there are seemingly but three directions in which uncertainty is likely to arise. These are: (1) the similarity in shape and in location of the crags, spines, obelisks, etc. produced by massive-solid eruptions, and the ordinary *cones of eruption* such as are typically illustrated by the one which forms from time to time within the crater of Vesuvius; (2) the similarity of obelisks, etc. to the tower-like forms produced by the erosion of craters within the conduits of which lava has cooled and hardened, so as to form what are termed *volcanic necks;* and (3) the tower-like forms resulting from the weathering of lava sheets which rest on less resistant and as is most commonly the case, incoherent sedimentary strata, or beds of tuff, and frequently termed *erosion columns.*

1. The necessity of distinguishing between massive-solid eruptions and cones of eruption arises principally from the fact that in fresh and well-characterized examples of each class, an elevation is present within an encircling crater. Cones of erup-

tion, however, in all known instances are composed of highly scoriaceous material, consisting of lava blocks, lapilli, bombs, cakes formed of splashes of liquid lava, dust, etc., and have a tube or conduit within, leading upward to a crater at the top. Such structures are in fact miniature volcanic cones of the same general character as the greater cones in the craters of which they are formed. In all of the characteristics mentioned the differences between cones of eruption and massive-solid extrusions are obvious and need no further discussion.

2. The similarity between volcanic necks exposed by the removal of their enclosing cones, and the tower-like forms produced by massive-solid extrusion, as in the case of Pelé, is most striking. This similarity approximates to identity, inasmuch as a volcanic neck and a volcanic obelisk may be portions of the same lava column; the former being the material within a conduit which cooled in place, or if forced upward did not emerge from its enclosing tube, while the latter represents the summit portion of a congealed lava column that has been forced out of its parent conduit.

Fresh and uneroded obelisks are not to be mistaken for volcanic necks exposed by erosion, because of their freshness and the presence about them of crater walls, or evidence of the destruction of such encircling rims by explosions, or their burial beneath the debris falling from the obelisks themselves, etc. It is in drawing distinctions between much weathered obelisks and volcanic necks when exposed by erosion, that difficulty is likely to arise.

In the case of well-characterized volcanic necks and good although much weathered examples of volcanic obelisks, it seems possible to draw a distinction, although their shapes, positions, etc., are essentially the same. The material forming a volcanic neck cools slowly on account of the insulation afforded by its enclosing cone, and would be expected to form a well crystallized and, in the case of most lavas, a porphyritic rock. Owing to slow cooling, also, the rocks of volcanic necks should exhibit a well defined columnar structure. Such we know to be the case in certain typical examples situated in the northwestern part of New Mexico and having a height of from 800 to 1000 feet above the adjacent plain, concerning which Major C. E. Dutton* writes as follows: "In all of these necks the basalt is columnar. The columns stand or lie in all sorts of attitudes, and in most cases are curved. Frequently they are grouped in radiating *fasciæ*, and at times are flexed and reflexed." The columns are described as varying in size from five or six inches to more than twenty feet across; the larger ones being generally vertical.

* Mount Taylor and the Zuñi Plateau, in Sixth Annual Report of the U. S. Geological Survey, Washington, 1886, p. 172.

Then, too, volcanic necks may contain rocks of any chemical composition ranging from ultra-basic to ultra-acid, that are extruded by volcanoes; while, as already stated, there seem to be good reasons for concluding that massive-solid eruptions occur only in the case of volcanoes which are supplied with highly refractory lavas.

With these considerations in mind, any monumental rock that simulates an obelisk in form, which is composed of basic or, more strictly, easily fusible material, might with greater probability be classed as a volcanic neck, then as a volcanic obelisk. And again, if the material composing such a monument is coarsely crystalline, and traversed by definite systems of joints, producing a well-defined columnar structure, the evidence is seemingly conclusive that it is not of the nature of a volcanic obelisk. In this connection the conditions revealed by the uncovering and erosion of subterranean intrusions, such as dikes, plutonic plugs, laccoliths, etc., need to be borne in mind, but space does not permit of considering them at this time.

Reverting to the case presented by Fernando de Noronha; the topographic form and prominent position of the Peak are such as to simulate in a remarkable way the conditions that may reasonably be supposed to pertain to a weathered obelisk; the rock of which it is composed, as reported by Darwin and Branner, is phonolite, and although, so far as I am aware, no analysis is available of this particular example, phonolites in general have approximately the composition indicated in the table presented above, and are to be included among the igneous rocks of medium fusibility. The rocks associated with the phonolite which forms the Peak of Fernando de Noronha and other neighboring elevations, as stated by Branner,* are of a basaltic type and compose the greater part of the island. From this same authority also, we learn that the phonolite of the Peak is conspicuously columnar; "The direction of the columns varies in some cases as much as fifty degrees. The lowest rocks of the Peak exposed in place are the irregular columns upon the eastern side. The columns are here very nearly vertical; but higher up, even upon this side, they twist and bend to the northeast and thus form the overhanging projection which is so remarkable a feature of this great rock. . . . . . On its western side the columns stand at various angles with the meridian, and usually at a high angle with the horizon." A comparison of this description with that of the columnar structure of the volcanic necks of New Mexico, quoted above, is highly suggestive.

It thus appears that the facts recorded concerning the Peak of Fernando de Noronha do not furnish positive evidence as to its mode of origin. Its shape and prominent topographic position are similar to those of the obelisk of Pelé, but on the

* This Journal, III, vol. xxxvii, 1889, p. 150.

other hand, correspond fully as well with the similar features of many volcanic necks. The chemical composition of the rock of which the Peak is composed, so far as suggestive of its degree of fusibility, is similar to that of the material erupted by Pelé; and so far as this fact has weight, it is evidently not opposed to the idea that the rock in question was extruded in a massive-solid condition. The well-defined columnar structure of the Peak, however, is so similar to that of many volcanic necks and still more numerous igneous dikes, and is so unlike the jointing observed in at least two examples of massive-solid extrusions, and so unlike, also, as we seem justified in assuming, the jointing to be expected in all such extrusions, that it favors the conclusion of its being a volcanic neck or a portion of an igneous dike, rather than of the nature of the obelisk of Pelé.

In reference to the criteria by means of which a distinction can be drawn between residual masses of lava sheets left as columns on the tops of hills or buttes, and obelisks of the Pelé type, but little need be said, since even a cursory examination of such monuments of erosion is usually sufficient to reveal their history. Erosion columns may be composed of any variety of volcanic rock, but as is well known, are most commonly basaltic, are usually vertically jointed and frequently conspicuously columnar, and rest on soft or incoherent material. In most instances, also, in regions where one such residual column occurs, others of similar nature are apt to be present, as well as flat-topped mesas and even broad table-lands. Thus in the nature of the material of which the columns referred to are composed, and in their structure and associations, they differ widely from massive-solid extrusions.

It is at present impracticable to apply the above mentioned criteria to the columns in the Deccan trap regions of India, referred to by Strachey, except so far as topography and the general nature of the rock are concerned. Topographically the columns represented in the sketch mentioned on an early page of this essay, seem to agree much more nearly with erosion columns than with volcanic obelisks, a view which is sustained by the presence of two examples near each other. The Deccan trap is composed of basaltic rock, such as is common in erosion columns and not as yet known to occur in volcanic obelisks. The evidence seems, therefore, to indicate that the columns in question are residual masses left by the nearly complete erosion of a formerly widely extended sheet of lava.

From the considerations presented in this essay, it will be seen that the recent eruptions on Martinique have made important contributions to both geology and geography. In the investigation of volcanoes geological and topographical studies go hand in hand and mutually assist each other.

ART. XXIV.—*On a New Nepheline Rock from the Province of Ontario, Canada;* by FRANK D. ADAMS.

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IN a paper which appeared in this Journal some years since,* the discovery of a large body of nepheline syenite in the township of Dungannon, in eastern Ontario about 85 miles northwest of Kingston, was recorded. As stated at the time, this occurrence is of large dimensions and the rock constituting it is in many respects remarkable in character. The discovery was one of the first results of a geological survey of this part of Ontario—at that time, geologically speaking, a *terra incognita* —which had just been undertaken by the writer for the Geological Survey of Canada. As the survey was continued during several succeeding summers, many additional occurrences of nepheline syenite were discovered and mapped, and as the result of more extended study the area is now known to present one of the most extensive and interesting developments of nepheline-bearing rocks which are known to occur anywhere. The geological maps of the area in question, by Dr. Barlow and the writer, are now completed and are being engraved, and it is expected that they, with the accompanying report, will be ready for distribution shortly. During the progress of the survey, Prof. Miller and Dr. Coleman of the Ontario Bureau of Mines visited the district and described certain of the occurrences of the nepheline syenite in papers published in the Reports of the Bureau and elsewhere.

When engaged in elaborating their Quantitative System for the Classification of Igneous Rocks, Messrs. Iddings, Cross, Pirsson, and Washington found that certain subdivisions of their scheme had no representatives amongst the rocks hitherto described. One of these subdivisions was Order 8 of the Peralkalic Persalanes, to which would belong nepheline syenites very poor in feldspar and very rich in nepheline, with perhaps allied varieties of related rocks. As it has been mentioned in the paper on the Dungannon nepheline syenite, that in that district rocks composed almost exclusively of nepheline occurred, the authors of the Quantitative Classification suggested that this order might be called Ontarare. No analysis, however, of any of these rocks had then been made, so that their precise composition remained somewhat doubtful. The name Ontarare, however, was given to the order, the present writer undertaking to make good the claim of the Province to the bestowal of the name, by describing an Ontarare from the district in

* F. D. Adams: On the Occurrence of a Large Area of Nepheline Syenite in the Township of Dungannon, Ontario, this Journal, July, 1894.

question which would serve as a type for the order. It is the purpose of the present paper to make good this undertaking by describing the first Ontarare.

The nepheline syenites of eastern Ontario, while always presenting the same general character, are represented by many varieties. The rock is usually coarse in texture, while in some of its pegmatitic developments the most extraordinary size of grain is attained. In one occurrence near the village of Gooderham in the township of Glamorgan, consisting of nepheline, albite, and an occasional individual of lepidomelane, the nepheline masses—for the most part single individuals—are often as much as three feet in diameter; while in several other occurrences nepheline syenite pegmatites of almost equal coarseness of grain have been found. The rock, furthermore, differs from that of most nepheline syenite occurrences, in that it commonly presents a more or less distinct foliation or gneissic structure, which foliation is not due to crushing *in situ* with the development of cataclastic structure, but is produced by a parallel arrangement of the constituent minerals, which arrangement seems to be a primary one or is at least unaccompanied by pressure phenomena.

The nepheline syenites of the region, furthermore, show a wide variation in mineralogical composition, several varieties often occurring together in the same mass, forming rude bands which coincide in direction with the foliation, thus serving to accentuate this and render it more pronounced.

The iron-magnesia constituent which is most commonly present is hornblende, represented by alkali-rich varieties, of which hastingsite may be taken as a type.* Pyroxene, however, replaces this in some cases and biotite in others. In some places these minerals preponderate over the colorless constituents of the rock and in these varieties garnet locally occurs in considerable amount. These dark bands, or schlieren, are, however, not very common and the prevailing facies of the rock is one which is light in color owing to the abundance of feldspar and nepheline. In certain occurrences other minerals which usually play the part of accessory constituents—such as corundum, sodalite, and cancrinite—attain more prominence, the first mentioned mineral now being very extensively mined in an occurrence of the syenite, near Combermere; while some of the largest masses of sodalite† which have ever been found are those which have been obtained from the nepheline syenite in

* F. D. Adams and B. J. Harrington: On a New Alkali Hornblende and a Titaniferous Andradite from the Nepheline Syenite of Dungannon, Ontario, this Journal, March, 1896.

† B. J. Harrington: On Nepheline, Sodalite and Orthoclase from the Nepheline Syenites of Dungannon, Hastings Co., Ontario, this Journal, July, 1894.

the township of Dungannon, to the east of the village of Bancroft.

These nepheline syenites occur cutting the rocks of the Grenville series, which consist largely in this district of crystalline limestones. Their wall rock consequently in almost every case is limestone. The only occurrence which is not directly associated with large masses of this rock is a large isolated intrusion in the township of Methuen, where the country rock is granite and amphibolite, the latter holding only a few small limestone bands.

With this is connected one of the most curious phenomena presented by these nepheline syenites, namely, the presence in them almost everywhere of calcite. This calcite when appearing in the analysis of a rock at once suggests an advanced stage of alteration, since calcite when found in igneous rocks is almost invariably a secondary product. In other cases calcite in plutonic rocks has been supposed to occupy miarolitic druses and to have been deposited in these by percolating waters.

A very careful examination, however, of the calcite-bearing occurrences of nepheline syenite in the various parts of this area has clearly shown that in the case of these rocks the calcite represents inclusions of the crystalline limestone penetrated by the intrusion, a fact which receives additional substantiation in the fact that in the Methuen occurrence, when the wall rock is not limestone, the nepheline syenite does not contain calcite. Along the borders of the intrusion, the nepheline syenite is seen to eat into the limestone and to enclose large masses, the constituent minerals of the syenite growing into the substance of the limestone, often with well defined crystal terminations. These masses often show a coarsening in grain as a result of the metamorphic action of the intruding rock. On receding from the contact, the inclusions become less numerous and smaller, and eventually the large masses are disintegrated into separate individuals of calcite or small groups of calcite grains. These, under the microscope, can be seen as rounded, often perfectly round, inclusions completely enclosed in a single individual of nepheline or other constituent of the nepheline syenite, or lying between other constituents of the rock, which latter can be seen to have grown into the calcite. In these cases all the minerals are perfectly fresh and unaltered, and, while the constituent minerals of the nepheline syenite rarely show pressure phenomena, the calcite individuals are often seen to be much bent and twisted and to display marked strain shadows, the movements displayed being those which overtook the limestone before the intrusion of the syenite into it.

It being, therefore, clearly recognized that the calcite is some-

thing foreign to the original magma and that it merely exists in the rock in the form of inclusions, in calculating out the mineral composition of the rock the calcite is set aside and the primary magma regarded as having the composition of the calcite-free rock. The nepheline syenite of the island of Alnö,* it may be mentioned, is characterized by the presence of calcite which is not of secondary origin, whose mode of occurrence in many respects is very similar to that of the calcite found in the nepheline syenite of Ontario.

Seven typical varieties of the rock have been analyzed and these serve to show the range in composition displayed by the magma. Of these, three were found to belong to the class of the Persalanes and to the sub-class Pesalone; using the nomenclature recently proposed by Messrs. Cross, Iddings, Pirsson and Washington,† while three others belong to the class Dosalane and the sub-class Dosalone. One is a Phlegrose, one a Vulturose and one a Miaskose, while two are referable to Essexose and one is a Kallerudose. These will be fully described in the forthcoming Report to which reference has already been made.

In addition to these there is the rock described in the present paper. This is a variety of the nepheline syenite which is almost free from feldspar and which consists essentially of nepheline and the iron-magnesia constituent, in this case hornblende. It occurs in the township of Monmouth, about 25 miles west of the township of Dungannon. Here, on lots 9, 10, 11 and 12 of ranges VII to VIII, a mass of nepheline syenite breaks up through a great band of crystalline limestone. The southern limit of this mass is unfortunately mantled by drift, so that its extension in this direction is somewhat uncertain. It has, however, the form of a flattened ellipse, the longer diameter measuring one mile and the shorter diameter about half a mile, and is completely surrounded by the limestone. The mass holds many inclusions of the limestone through whose shattered mass it penetrates. These included limestones frequently are coarsely crystalline and are more or less impure from the presence of secondary silicates developed by the contact action. These masses have the appearance of being in process of replacement by the intruded magma. The nepheline syenite in some places along its contact with the limestone is rich in hornblende, but elsewhere along the border it contains but a very small proportion of the dark constituent, so that no distinct endomorphic action can be traced to the influence of limestone. In some few places, however, near the limestone

* Hogbom, A. G.: Ueber das Nephelinsyenitgebiet auf der Insel Alno. Geol. Fören. i. Stockholm Förh., Häft. 2, 1895, p. 140.

† Quantitative Classification of Igneous Rocks, University of Chicago Press, Chicago, 1903.

the syenite holds scapolite. Taking the intrusion as a whole it may be said to consist essentially of albite, nepheline and hornblende, but as is so frequently the case in this region it shows a wide variation in relative proportion of the constituents in different places. In some places it is rich in feldspar, while elsewhere the nepheline almost entirely replaces this mineral. In the latter case the nepheline is usually associated with a considerable amount of hornblende, in addition to which in many cases a small amount of red garnet is present.

The feldspathic and feldspar-free varieties run in rudely parallel bands or schlieren. These are often several feet in width and may be traced for several hundred yards along the strike of the banding. They represent distinct magmas resulting from extreme differentiation. The rock here described was collected from one of the bands six feet in width and several hundred yards long.

The rock is coarse in grain and consists essentially of white nepheline and black hornblende, the former preponderating largely. It thus has a rather striking appearance on the fresh fracture. On the weathered surface the contrast presented by the two minerals is less striking, as the nepheline assumes a pale gray color. Under the influence of the weather, the nepheline, as is always the case with these rocks in this district, presents the appearance of having been dissolved away, the weathered surface being smooth and recessed, the hornblende and the accessory feldspar and cancrinite of the rock standing out from the surface of the nepheline.

Under the microscope the rock is seen to consist essentially of nepheline and hornblende, with plagioclase, cancrinite, and calcite as accessory constituents, as well as sodalite, apatite, sphene, biotite, pyrite and iron ores, these latter minerals being present in extremely small amounts.

The Nepheline occurs in large well-defined grains, presenting the usual characters displayed by the species. It is clear and fresh.

The Hornblende is green in color, the pleochroism and absorption being as follows: $\mathfrak{a}=$ pale greenish yellow. $\mathfrak{b}$ and $\mathfrak{c}=$ very deep green. The absorption is $\mathfrak{c}=\mathfrak{b}>\mathfrak{a}$. The maximum extinction observed in the sections of the rock was 19°. It is an alkali hornblende, containing less iron than hastingsite, but, like it, as shown by the calculation of the analysis of the rock, belonging to the division of the Syntagmatites.

The Plagioclase is present only in very small amount and is in some cases untwinned, while in other cases it shows a faint, polysynthetic twinning. In thin sections it bears a very close resemblance to the nepheline, and when untwinned it is difficult in all cases to distinguish the two minerals. When a sec-

tion is treated with acid and etched, however, the plagioclase is seen to occur in individuals of a more or less rounded form or with curving outlines, lying between the nepheline grains or enclosed in the latter. The feldspar isolated from another variety of the rock in the same occurrence was found to be albite, and this feldspar has, therefore, been taken as albite in calculating the Mode of the rock.

The amount of Cancrinite present varies very considerably in different specimens of the rock. In the specimen analyzed about 5 per cent was found. In other specimens more is found, although in no case is it very abundant. It is clear and colorless, but is at once distinguished from the nepheline when examined between crossed nicols by its much higher polarization colors, which in thin sections frequently rise to a blue of the second order. It is clear and free from interpositions and in convergent light is seen to be uniaxial and negative. It also shows a slight but distinct dispersion of the bisectrices, giving a brownish and a bluish tint on either side of the position of maximum extinction. When separated by Thoulet's solution, the mineral was found to have a specific gravity between 2·48 and 2·44, and to be readily decomposed when heated with dilute hydrochloric acid with the evolution of carbonic dioxide and with subsequent gelatinization. The cancrinite occurs in the nepheline in the form of narrow strings or more rarely in little bunches of grains. These usually follow the course of minute cracks or cleavage lines, but also are frequently seen to follow the boundaries of individual grains of nepheline on their contact with grains of other minerals. Thus between crossed nicols they appear as a brilliant edging about hornblende individuals or about calcite inclusions in the nepheline, the small prismatic individuals of cancrinite being arranged with their longer axes at right angles to the contact or to the course of the crack, as the case may be. The cancrinite has the appearance of being an alteration product of the nepheline.

The Calcite occurs in large single individuals, which are found as inclusions in both the hornblende and the nepheline. The single individuals are often perfectly circular in outline, and the enclosing mineral is perfectly fresh and unaltered and is sharply defined against them. In other cases the same large calcite individuals lie between the other constituents of the rock, in all cases having the character of inclusions. They generally show very marked strain shadows, while the other constituents show but little or no evidence of pressure phenomena.

The Apatite is found as occasional more or less rounded individuals, enclosed in the nepheline or hornblende, but, like the other accessory constituents, merits no especial description.

An analysis of the rock made for me by Mr. M. F. Connor gave the following results:

SiO_2	39·74
TiO_2	·13
Al_2O_3	30·59
Fe_2O_3	·44
FeO	2·19
MnO	·03
CaO	5·75
MgO	·60
K_2O	3·88
Na_2O	13·25
CO_2	2·17
SO_3	trace
Cl	·02
S	·07
H_2O	1·00
	99·86

If, following the methods of the Quantitative Classification, the Norm of the rock be calculated, that is to say the proportion of standard minerals which would give a magma of this composition, or in the form of which the rock under other conditions of cooling might have solidified, this is found to be as follows:

Anorthite	12·51
Nepheline	67·72
Leucite	8·28
Olivine	3·70
Akermanite	·40
Magnetite	·70
Ilmenite	·30
Pyrite	·14
Calcite	4·92
	98·67
Water	1·00
	99·67

This gives the rock the following position in the Quantitative Classification:

Class 1—Persalane.
Order 8—Ontarare.
Rang 2—(Domalkalic).
Sub-rang 4—(Dosodic).

As this is the first Ontarare which has been described, the rangs and sub-rangs have received no names as yet. It is proposed, therefore, to call rang 2, Monmouthase, and sub-rang 4, Monmouthose, from the township of Monmouth in which this rock is found, while, as an ordinary designation, the name Monmouthite may be applied.

The Mode, or actual mineralogical composition of the rock, is quite different from the Norm, as given above, no leucite, anorthite, olivine, or akermanite being actually present. The mode is *abnormative** to a striking degree.

The Mode is as follows:

Albite	1·83
Nepheline	72·20
Sodalite	·28
Cancrinite	5·14
Hornblende	15·09
Hematite	·50
Calcite	3·12
Pyrite	·14
	98·30
Water	·50
Excess of Al_2O_3	1·20
	100·00

In calculating this mode the nepheline is taken as consisting of soda nepheline and kaliophyllite, in the proportions of 5 to 1, which is the composition of the nepheline of the nepheline syenite occurring further to the west in the area of the township of Dungannon.† One-half of the water found in the analysis is considered as being present in the cancrinite, the remainder being regarded as belonging in part to the hornblende and as existing in part as hygroscopic water. This gives cancrinite in about the proportion in which it seems to be present in the thin sections of the specimens analyzed.

The various bases not required by the other minerals and remaining over to form the hornblende, are present in the proportions required to form syntagmatite; which are the proportions in which these bases are found in the hastingsite of the Dungannon nepheline syenite. The hornblende has accordingly been calculated as syntagmatite, using the theoretical values given by Zirkel: Lehrbuch der Petrographie, vol. i, p. 303. This accounts for the existing percentages of all the constituents of the rock, with the exception of an excess of 1·20 per cent of alumina.

Of the rocks hitherto described, those which bear the closest resemblance to Monmouthite are the Urtites of the Peninsula of Kola.‡ These, however, belong to the class of the Dosalanes.

Geological Department, McGill University, Montreal, P. Q.

* See Quantitative Classification (loc. cit.), p. 150.

† B. J. Harrington: loc. cit.

‡ W. Ramsay: Das Nephelinsyenitgebiet auf der Halbinsel Kola, Fennia. 15, No. 2, p. 22.

ART. XXV.—*Note on a Calcite-Prehnite Cement Rock in the Tuff of the Holyoke Range;* by B. K. EMERSON.

AT Lymans Crossing, now abandoned, a mile north of Smiths Ferry, and just south of the river notch through the Holyoke Range, is a large cutting through the posterior trap sheet, exposing the upper surface and the superjacent tuff beds. The cementing material which holds the tuff fragments together at the base of the bed is quite peculiar. It looks like a felsite or a compact sedimentary limestone. It is clear gray with faint shade of green.

The small angular fragments of trap enclosed in this cement are often one to three inches apart, showing that it cannot be a simple secondary interstitial cement produced by a later infiltration. It contains here and there rounded or pear-shaped cavities, filled with coarse calcite, which seem to be certainly steam holes. Minute scales of graphite just visible to the eye are quite generally distributed and are slightly larger and more abundant where the cement rock borders against the trap. The scales are graphite and not molybdenite, since they float in Thoulet's solution.

Under the microscope the trap fragments are seen to be normal and to preserve their usual characters up to their borders.

The cement rock has a confused crystalline texture and large stationary black crosses appear everywhere over the surface. It is made up in about equal parts of calcite in shapeless areas with very irregular boundaries, and a colorless prehnite in coarse rudely radiating prisms and wheel-shaped forms which plainly cause the black crosses. A few blades of a pale brown biotite are present but may be secondary. Distinctly secondary are the angular fragments of acid plagioclase and microcline, which have a granitic aspect. The rock has sp. gr. = 2·86, which indicates that a little more than half its mass is prehnite, and the study of the section confirms this. The small crumpled graphite scales are also secondary, and must have come from west of the axis of the Green Mountains, twenty-five miles west, or from the Brinefield rusty schist area fifteen miles east. The brightly shining scales resemble those from the western area. The same graphite is found extensively in the adjoining sandstone. There is also a small amount of a primary albite deposited by the same waters from which the prehnite crystallized and having the same undulose extinction which characterizes the albites deposited by heated waters in the cavities in the trap.

The outburst of the tuff followed immediately on the outflow of the trap sheet and many of the scoriaceous bombs which first fell sank quite deeply into the latter and can be seen enclosed in compact trap as at the western pavilion in Mountain Park.

The cement rock formed at the base of the tuff in waters which were slightly contaminated by the materials of the sandstone, the graphite scales being especially far travelled because of their indestructibility and lightness. It increased to very considerable thickness between the trap fragments and crystallized so rapidly and in such high temperature that it enclosed pear-shaped steam holes like a scoria. After the temperature had fallen below the solution point of prehnite, these cavities were filled by calcite.

Amherst College, Mass.

Art. XXVI.—*The Developmental Changes in some Common Devonian Brachiopods;* by Percy E. Raymond. (With Plates XII–XVIII.)

Introduction.

Certain layers of impure, clayey limestone from the Moscow (Hamilton) shales which occur in a ravine near Canandaigua Lake, N. Y., were found by Dr. John M. Clarke to contain fossils whose shells had been so completely replaced by silica that when the rock was etched in acid the shells were left in as perfect condition as when they were buried in the limy clay of their native sea-bottom. A large quantity of this material was obtained by Prof. C. E. Beecher, and through his kindness part of it has been placed at the disposal of the writer for study. About 65 pounds of the rock were treated with hydrochloric acid, and the shells washed from the clay which remained after the calcium carbonate had been removed. From this material about 15,000 nearly perfect specimens have been selected, while a much greater quantity of fragmentary material was discarded. Nearly all classes of invertebrate animals are represented in this collection, but the brachiopods are most numerous, comprising two-thirds of the total number of individuals, and furnishing at least thirty-five hundred specimens of a single species (*Chonetes scitulus*). Next in abundance to the brachiopods are the Bryozoa, then the Crustacea, worm tubes, pelecypods, gastropods, corals, and cephalopods, in the order named. The echinoderms are represented only by crinoid columns and the sponges by a few spicules. A few fish scales were also found. Chitinous shells of the *Lingula* type do not appear to have been preserved, and some of the Dimyarian bivalves occur only as casts.

The majority of shells are white, but some are dark gray to black, while the trilobite tests are light to dark brown. The color seems to be fairly uniform for all the individuals of the same species. For instance, there are two species of *Monotrypa*, and all the individuals of both species are black, yet most of the Bryozoa are light colored. In the case of *Chonetes mucronatus*, however, while most of the specimens are dark, a few are white.

The state of preservation of the fossils in this material is remarkable, even the finest details being retained, which shows conclusively that the shells were not subjected to any rough wave action after the death of the animal. The graceful fronds of the Fenestellidæ are obtained as they grew, and the delicate spines of the Productidæ and the spiniform exten-

sions of the cardinal angles of the young *Stropheodonta* are in perfect condition. Unfortunately the brachial loops and spires are not so well preserved, though many specimens of *Eunella* show a large part of the loop, and in one young form it is entire. Many specimens of *Tropidoleptus* retain the delicate median septum and the crura, but the loop was not observed.

Perfect examples of the little ostracods of the genera *Halliella* and *Kirkbya*, whose shells are merely a fine network, were obtained, as well as many of the *Rhombopora*-like Bryozoa, covered with minute spinules. The pelecypods, which are nearly all immature individuals, are excellently preserved, and many of them retain the prodissoconch.

The advantage of this method of collecting is shown by the great number of specimens of supposedly rare species obtained. *Pholidops hamiltoniæ*, which is rare in ordinary collections, is extremely abundant in this material, only one species being more common. *Pholidops oblata*, of which not more than a dozen specimens have been found in other localities, has here been obtained by the hundreds, while *Ascodictyon stellatum*, *Autodetus Lindstræmi*, and the ostracods, which are seldom found in any quantity, are very common. The whole fauna consists of about 125 species, 115 of which have been thus far identified, there being 10 or 12 whose specific identity is uncertain, and some of these are probably new. The fauna is distributed as follows:—Crustacea: Trilobita, 5 species; Ostracoda, 11; Cephalopoda, 1; Gastropoda, 8; Pteropoda, 3; Pelecypoda, 16; Brachiopoda, 39; Bryozoa, 18; Vermes, 6; Anthozoa, 5.

A large proportion of the individuals of the Brachiopoda are in immature stages, many of them being less than 1^{mm} in length. From that size there are specimens showing all gradations up to the adult, and, in many cases, to senile stages. Series representing all these stages have been selected wherever possible, and carefully studied, in order to ascertain what changes took place in the shell during the lives of the individuals of the various species.

The pioneer work of this sort was done by Beecher and Clarke on material obtained from Waldron, Indiana. In the memoir published by them giving the results of this work, the developmental stages of 25 species, belonging to 18 genera, were described. Later work by Beecher, Schuchert, and Cumings, has added full descriptions of several more. Among the fossil brachiopods, 2 genera of the Rhynchonellidæ, 3 of the Atrypidæ, 1 of the Craniidæ, 1 of the Eichwaldiidæ, 4 of the Strophomenidæ, 4 of the Orthidæ, and 1 of the Porambonitidæ, have been studied in this way up to the present time.

From the present material the writer has been enabled to study the complete series of changes in 20 other species, and a partial series in 4 more. This list comprises 15 genera, 11 of which are not represented in the work previously done. These genera belong to the families Centronellidæ (*Trigeria*), Terebratulidæ (*Eunella*), Terebratellidæ (*Tropidoleptus*), Spiriferidæ (*Cyrtina*, *Delthyris*), Craniidæ (*Pholidops*, *Craniella*), Strophomenidæ (*Stropheodonta*, *Pholidostrophia*), and Productidæ (*Chonetes*, *Strophalosia*). *Crania*, *Rhipidomella*, *Spirifer*, and *Orthothetes* are here represented by Devonian species, while the previous work has been done on those from the Silurian; interesting points may be therefore obtained by comparing results.

The present paper is an abstract of the results attained from this study, and gives a summary of the most interesting facts ascertained in regard to 17 of these species.

Crania crenistriata Hall.

Pal. N. Y., iv, 1867, p. 28, pl. 3, figs. 13–16.

The smallest specimen of this species is 2·66^{mm} long and 3·33^{mm} wide. At the apex it shows the nepionic shell, which is similar in form to the adult, but non-plicate. It is 1·46^{mm} long by 1·66^{mm} wide. In this species, and in *Craniella hamiltoniæ*, the young shells have, as a rule, more conical dorsal valves than the adults.

Stropheodonta inæquistriata Conrad.

(Plate XIII, Rows 2, 3, and 4.)

Pal. N. Y., iv, 1867, p. 93, pl. 12, figs. 6–8.

Nepionic Stage.—In the nepionic stage the shell of this species is oval in outline, and wider than long. Both valves are convex, though in some specimens the dorsal valve becomes flat in front. The latter valve bears a narrow median fold which extends about half-way to the front. Otherwise the shell is smooth. The length of the average specimen in this stage is ·42^{mm} and the width ·54^{mm}.

Changes during Development: Outline.—Immediately after the nepionic stage the width at the hinge becomes greater than that below, and remains so through all succeeding stages. The cardinal extremities are most alate during the adolescent period, and all immature forms are characterized, when perfect, by long hinge lines. In the senile state, the cardinal angles are not so extended, but the width at the hinge is still the greatest width. (Compare the young specimens, Nos. 14 and 15 of the series, with the adult and senile individuals on Plate XIII, Row 4.)

Convexity of Valves.—In the nepionic stage both valves are convex, but, when a length of about $\cdot 5^{mm}$ is reached, the dorsal valve becomes concave in front and follows very closely the curvature of the other valve throughout succeeding stages. Shells from 1 to 6^{mm} long are very slightly convex, sometimes almost flat, but, as they grow older, the convexity increases until in the gerontic stage they are almost hemispherical.

Muscle Scars.—The migration of the muscles in this species during the life history is most interesting. The normal form of the scars in the ventral valve of the adult is shown in Paleontology of New York, Vol. 4, Plate 15, figure 10, and figure 2h, Plate 18, gives the interior of a dorsal valve at the same stage. Figure 2h, Plate 18, and figure 11, Plate 15, show the ventral and dorsal valves of a senile individual.

In the smallest ventral valve in which the muscles have left distinguishable impressions (4×4^{mm}) the diductors have oval, somewhat widely separated scars, between which are the two small adductors, one on either side of the median line. The diductors are bounded posteriorly by two ridges making a wide angle with each other. The adductor scars have faint ridges on either side and another ridge between them. In a little later stage these three ridges become sharp and distinct. The median one runs nearly to the beak, while the others remain short, sharp, and rather high, curving outward. In the later neanic stages these ridges arch over and join the ridges which bound the diductors.

The two ridges bounding the posterior borders of the diductors send off processes a short distance in front of the hinge, which turn inward and run parallel for a little way. They rise sharply from the floor of the valve, and overhang on the side toward the median line. In the later neanic stages the whole extent of the diductor impressions is bounded by a low, sharp ridge that is later resorbed.

During the adult stage the parallel portions of the two ridges which bound the diductors are extended and strengthened, and the divergent portions resorbed. The median ridge becomes stronger and rounded, and the two sharp ridges which separated the adductors from the diductors disappear. An almost square muscle scar is thus produced, which has less area for attachment of the muscle, but is better located for a direct pull on the cardinal process.

In the dorsal valve the two pairs of adductors occupy a small space in front of the cardinal process, and are usually bounded by a low ridge. The outer pair, the posterior adductors, make up most of the scar. They are small, roughly triangular, and situated close to the front of the cardinal process. The anteriors are narrow, and are situated on a platform between, and

slightly above, the level of the posteriors. Between the scars, on the median line, is a low, short septum which is hardly elevated above the surface of the shell in young specimens, but becomes prominent in adults. On either side of it is a low ridge extending back nearly to the base of the cardinal process. In the adult the portion of these ridges in front of the muscle scars becomes high and incurved, and may function as a support for the brachia. These ridges are short, and their anterior ends are not half-way to the front of the valve. They appear to be homologous with similar ridges in *Chonetes scitulus*, which are certainly connected with the brachia. The structure of the muscle scars and ridges in this species should be compared with that in the dorsal valve of *S. concava*. In neither case do the ridges in front of the muscle scars function as the attachment for muscles, as has been suggested by many writers.

Hinge Structure.—A few of the smaller specimens show a short exsert pedicle tube. In adult and senile stages the pedicle opening is pushed back onto the beak, and is very minute.

Stropheodonta perplana Conrad.

(Plate XIII, Row 1.)

Pal. N. Y., iv, 1867, pp. 92, 98, pl. 11, fig. 22; pl. 12, figs. 13–15.

Protegulum.—The protegulum of this species is nearly circular, biconvex, with arcuate hinge. It measures $\cdot 10 \times \cdot 10^{mm}$ on one specimen, and $\cdot 12 \times \cdot 12^{mm}$ on another.

Nepionic Stage.—The shell in the nepionic stage is convex in both valves, nearly as long as wide, and both valves are smooth. On the dorsal valve is a fold which extends nearly to the front of the shell (figure 1).

Changes during Development.—Like *S. inæquistriata*, this shell becomes strongly alate in the neanic stages and the hinge width remains the greatest width throughout life. (See specimens 4, 7, 10, and 14 of the series, for examples of this.) After the nepionic stage, the dorsal valve becomes first flat and then slightly concave. The shell remains nearly flat throughout all stages.

1

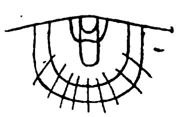


Figure 1. — *Stropheodonta perplana* Conrad; dorsal valve, showing shell in nepionic stage, the fold, and the origin of the striæ. ×16.

Muscle Scars.—In this species there is no change in the position of the muscle impressions during life. The adductor scars in the ventral valve are divided by a diagonal line into anterior and posterior elements, a fact not shown in calcified specimens.

Pholidostrophia iowaensis Owen.

Pal. N. Y., iv, 1867, p. 104, pl. 18, fig. 1.

Changes during Development.—This shell, like the other Stropheodontas, becomes strongly alate in the neanic stages, but the principal change during its development takes place in the adult and early senile stages, when the shell which has formerly been nearly flat is abruptly deflected in front, making the ventral valve very convex in this part, while the dorsal is correspondingly concave. The exterior is smooth in all stages. A single specimen from Eighteen Mile Creek shows a few distant radiating striæ, which may be taken as suggestive of an ancestral character.

2

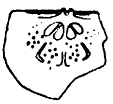


FIGURE 2.—*Pholidostrophia iowaensis* Owen; brachial valves, showing muscle scars and brachial ridges. Natural size.

Brachial Markings.—In front of the muscle scars of the brachial valve, there is, on each side of the strong median septum, a crescent-shaped ridge, which turns in rather abruptly as a sort of hook at the anterior end (figure 2). In adults these processes extend about two-thirds the distance to the front of the shell. In the young, they extend somewhat further forward and are more divergent. These ridges correspond, in position, with the brachial ridges of *Chonetes* and *Productus* and probably should be correlated with those markings. They have been given considerable taxonomic importance by some authors, the group of Stropheodontas which bears them being considered by Œhlert as forming a transition group connecting the Strophomenidæ and the Productidæ. It is probable, however, that the occurrence of these markings is due more to the age of the individual shell than to anything else, for with increase in the deposit of testaceous matter the brachial scars become more distinct in those species in which they are usually observed, and these scars are not confined to the Devonian Stropheodontas but can be seen in *Rafinesquina* from as old a formation as the Chazy; they are likewise well known to occur in *R. Jukesii* and *Stropheodonta profunda.**

The genus *Pholidostrophia* was suggested by Hall and Clarke to include a section of the Stropheodontas in which the shells were concavo-convex, had no striæ, and were strongly punctate. The interior of the dorsal valve was characterized by having three divergent ridges in front of the muscular area. *Stropheodonta nacrea* Hall, from the Corniferous and Hamilton, an unnamed species from the Corniferous, and *Stro-*

* See Hall and Clarke, vol. viii, pt. i, pp. 282, 283, figs. 19, 20; and pl. 20, fig. 30.

phomena lepis Bron., of the Middle Devonian from Eifel, Belgium, and the Asturias, were placed in this division.

The development of the hinge structure, form of shell, and convexity of valves is very similar in the three species (*S. inæquistriata*, *S. perplana*, and *P. iowaensis*) just described. The points of greatest difference are:

First: The Striæ.—*S. inæquistriata* produces new striæ by implantation, *S. perplana* by both implantation and bifurcation, while *P. iowaensis* has normally no striæ at any stage of development.

Second: Muscle Scars.—*S. inæquistriata* has a type very different from that of the other two, and in the ventral valve there is a change in the form of the muscles during the ephebic and gerontic stages. In the other two no such change has been observed.

3

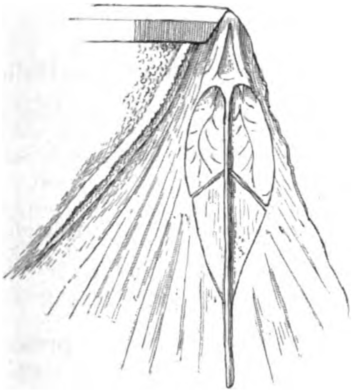


FIGURE 3.—*Stropheodonta junia* Hall; part of the muscle area of a ventral valve, showing the anterior and posterior elements of the adductors, and the pedicle muscle scar. × 3.

Comparing the scars in the ventral valves of *Stropheodonta junia* (figure 3), *S. perplana*, *S. demissa*, and *Pholidostrophia iowaensis*, it is at once seen that they are very similar. In each the diductors are broad, flabelliform, separated by a low septum, and bounded on their posterior lateral edges by more or less papillose ridges. Between the diductors are the elongate scars of the adductors, two pairs in each case. In the dorsal valves of *S. demissa*, *S. perplana*, and *P. iowaensis*, there is more variation in the form of the scars, but it is a variation in the form of the limiting structures rather than in the shape of the scars themselves. In each, there are two pairs of scars, one pair somewhat anterior to and between the members of the other pair. In *S. demissa* and *P. iowaensis*

they are bounded by a low ridge in front, while in *S. perplana* the anterior margin is more indefinite.

The interior of the dorsal valve of *P. iowaensis* should also be compared with that of *S. profunda* Hall, from the Niagara.* In that species the form of the scars is almost exactly the same as in the Hamilton species, and in front of the scars there are two short curved ridges and a prolongation of the median septum. This species has been put in the division Brachyprion by Hall and Clarke.

Thus there are examples of four of Hall and Clarke's subdivisions,—Brachyprion, Leptostrophia, Pholidostrophia, and Stropheodonta (*S. demissa* type), which agree in internal structure, but have great variation in external ornamentation. These facts would seem to indicate that the name Pholidostrophia should be given the same taxonomic value as the names Brachyprion and Leptostrophia, instead of being raised to generic rank.

Orthothetes chemungensis Hall.

Orthothetes chemungensis var. *pectinacea* Hall.

(Plate XV, Row 1.)

Pal. N. Y., iv, 1867, p. 67, pl. 10, fig. 6.

Orthothetes chemungensis var. *arctistriatus* Hall.

(Plate XV, Row 2.)

Pal. N. Y., iv, 1867, p. 71, pl. 9, figs. 1–12.

The specimens of *Orthothetes* in the present collection represent the two varieties *pectinacea* and *arctistriatus* of Hall. Both develop in the same manner, the only difference being in the time of appearance of new striæ. In the adult these two forms can be separated only under the most favorable circumstances, yet the younger specimens are quite distinct. The variety *pectinacea* has from 15 to 19 strong elevated striæ, between which are lower interspaces containing from 1 to 3 striæ. In the variety *arctistriatus* the striæ are so crowded that this alternating appearance is not obtained.

Smallest Shell.—The smallest shell which retains both valves is ·73^{mm} long and 1·1^{mm} wide, with a hinge width of 1^{mm}. Both valves are convex, and the cardinal area is high. The delthyrium is almost completely closed by a strong, convex deltidium which is slightly prolonged at the apex, forming an exsert pedicle tube. On this specimen there are 13 striæ on the dorsal and 14 on the ventral valve. At the beaks can be seen the outline of the nepionic shell, which is almost

* Loc. cit.

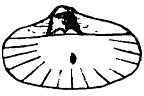
exactly circular, biconvex, and smooth. It is $\cdot 35^{mm}$ in length, but varies from that size to $\cdot 43^{mm}$.

Introduction of New Striæ.—The shell of the variety *pectinacea* has, up to a length of 1 to $1\cdot 2^{mm}$, from 13 to 15 sharp, simple striæ separated by spaces which are wider than the striæ. There then appear from 4 to 6 new striæ in the middle of the front, one implanted in each interspace in that region (figure 4). Specimen No. 1, on Plate XV, Row 1, shows the shell with the original striæ. Specimen No. 2 shows 5 striæ implanted in front. Later, more are implanted until there is one between each pair of the original striæ. The next step is the appearance of striæ in pairs, one on each side of each of the secondary striæ. (See specimens Nos. 8 and 10, Row 1, Plate XV.) At a still later stage more pairs are added, one on each side of those next previous to appear. In the variety *arctistriatus*, the method of development is the same, but the resulting appearance is somewhat different. In the earliest plicated stages there are from 15 to 19 sharp striæ. New striæ appear as before, but come in at earlier stages, thus covering the surface of the valve more completely and giving a more uniform appearance to the striæ. (Compare No. 6, Row 1, Plate XV, with No. 6, Row 2, and the last specimens in each row.)

4

FIGURE 4.—*Orthothetes chemungensis* var. *pectinacea* Hall; dorsal valve, showing earlier plications. ×12.

5



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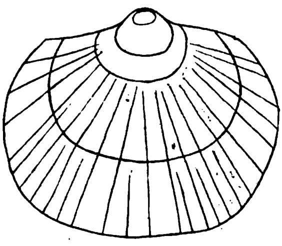

FIGURE 5.—*Orthothetes chemungensis* Conrad; specimen retaining both valves and showing pedicle tube and simple plications. ×16.

FIGURE 6.—The same species; ventral valve, showing pedicle tube which is somewhat broken at top, growth lines, and striæ. ×16.

Orthothetes bellulus Clarke.

(PLATE XV, Row 3.)

13th Ann. Rept. N. Y. State Geol., pp. 176, 187, pl. iv, figs. 2–4.

This species was described by Clarke from specimens found in the Marcellus, but the Hamilton forms from the Canandaigua

Lake locality differ only slightly from the type. As described by Clarke, the Marcellus specimens have from 18 to 20 plications; the greatest diameter is at the hinge, and there is no umbonal distortion. The Hamilton specimens, however, have from 24 to 30 plications, the width at the hinge is less than that below, and the cardinal area is high, the ventral umbo being on that account frequently distorted.

The developmental stages offer nothing new. The shell in the nepionic stage is very small, usually from ·10 to ·12^{mm} in length. In young stages there is an exsert pedicle tube, while in the adult a strong convex deltidium covers the delthyrium.

Summary.—The development of two other species of *Orthothetes* has been worked out: That of *O. subplanum* of the Niagara, by Beecher and Clarke,* and that of *O. minutus* of the Salem limestone, by Cumings.† *O. bellulus* has in its adult stage many characters which agree with the neanic stages of *O. minutus*. The latter species has, in its earliest plicated stage, 18 plications, and more are added in the same way as in *O. bellulus*. In the adult, dwarfed, there are 40 plications.

Comparing the development of *O. subplanum* of the Niagara with that of *O. chemungensis*, many differences are found.

First: Convexity of Valves.—The nepionic shells of *O. chemungensis* have the valves subequally convex, which is the adult state of *O. subplanum*, while its nepionic shell is concavo-convex.

Second.—In *O. subplanum* the cardinal area is low compared with the length of the hinge line and the adults are symmetrical. In *O. chemungensis* only in the early neanic stages are the shells perfectly symmetrical usually, though some specimens retain the low cardinal area and symmetry into the late neanic stages.

Third: Surface Characters.—The duration of the nepionic stage is about the same in both species. In the youngest specimen of *O. subplanum* figured by Beecher and Clarke, 2·25^{mm} long, there are 17 striæ, 6 of which are secondary. A specimen of *O. chemungensis* of similar length has from 28 to 35 striæ.

Fourth: Hinge Structure.—The young of both species have a strong convex deltidium which is prolonged into an exsert tube for the passage of the pedicle. In *O. subplanum* the deltidium ceases to grow at an early stage, while in *O. chemungensis* the deltidium continues to increase in size throughout all the stages.

* Silurian Brachiopoda. Memoirs N. Y. State Museum, vol. i, No. 1, 1889, p. 23, pl. ii, figs. 14–20.

† Am. Geol., vol. xxvii, March, 1901, p. 147, pl. xv, figs. 1–11.

The first three of these differences point to an earlier acquisition of the characters through acceleration. The last would tend to show that *O. chemungensis* was in a progressive rather than a retrogressive line of development.

Chonetes coronatus Conrad.

(PLATE XVI, ROWS 3, 4.)

Pal. N. Y., iv, 1867, p. 133, pl. 21, figs. 9–12.

Chonetes scitulus Hall.

(PLATE XIV.)

Pal. N. Y., iv, 1867, p. 130, pl. 21, fig. 4.

Chonetes mucronatus Hall.

(PLATE XV, ROWS 4, 5.)

Pal. N. Y., iv, 1867, p. 124, pl. 20, fig. 1; pl. 21, fig. 1.

Chonetes robustus sp. nov.

(PLATE XVII, ROWS 1, 2.)

The New Species.—There are in the collection from Canandaigua Lake about 50 specimens of a *Chonetes* which differs in important characters from any described species. The shell is strongly concavo-convex, wider than long, with from 20 to 40 strong, sharp, equal striæ which increase toward the front by bifurcation and implantation. The umbo is smooth for a distance of from 1 to $2{\cdot}5^{mm}$, cardinal area of ventral valve narrow, concave, and the delthyrium covered by a convex deltidium. Pedicle opening minute, encroaching upon the ventral beak. The posterior margin of the area bears from 4 to 6 pairs of short divergent spines. For this species the name *Chonetes robustus* is suggested.

This species is more nearly related to *Chonetes coronatus* than to any other known brachiopod. It differs from it in the smaller size of the adult, the much greater convexity of the ventral valve, the fewer and coarser striæ at the same stage of growth, the smoothness of the umbos, the fewer pustules on the interior of the dorsal valve, and the later emergence of the first spines on the posterior margin. On the adult of this species there are 6 striæ in the space of 5^{mm} on the front, while in *C. coronatus* there are 11. In convexity and size this species resembles *C. mucronatus*, but is easily distinguished by the sharpness of the striæ and the angle of divergence of the spines.

The figures on Plate XVII are all enlarged two diameters.

Summary.—All the species in the collection have the same type of changes in development; hence they will be discussed together.

Proteguhim.—The shell at this stage is exceedingly small and in none of the specimens of the present material are the beaks well enough preserved to show the proteguhim. From Beecher's work it is known that in *C. scitulus*,* the protegulum is nearly circular in outline ($\cdot 117^{mm}$ long and $\cdot 111^{mm}$ wide, according to the figure), with a strongly arcuate hinge.

Nepionic Stage.—The species agree in having the shell at this stage convex in the ventral valve, convex at the umbo, and concave or flat in front on the dorsal valve. This is an advance on the condition in *Stropheodonta*, where the dorsal shell is convex during the whole of the nepionic stage.

The ventral valve always has a narrow sinus, and the dorsal valve a corresponding median fold, with usually two less definitely marked lateral folds.

The outline is subcircular, though the width is frequently a little greater than the length. The hinge is somewhat arcuate. The length of the nepionic shell varies considerably in the different species, but is always less than one millimeter. It is least in *C. coronatus* and greatest in *C. mucronatus*.

7

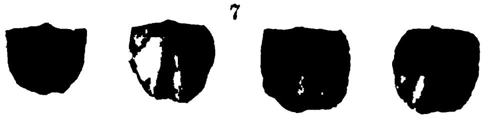

FIGURE 7.—*Chonetes scitulus* Hall; ventral and dorsal valves, showing fold and sinus and plications of very young specimens. × 12.

Pauciplicate Neanic Stage.—In this stage new striæ are introduced by implantation and not by bifurcation of the older ones. The striæ are strong, simple, and separated by spaces as wide as the striæ themselves. The number of plications is not great. In *C. coronatus* and *C. scitulus* the largest number is usually 13 on the ventral valve and 12 on the dorsal. In the other species there are more, but usually less than 20.

The shell is about one-fifth wider than long and gently concavo-convex. The first spines, usually two or three pairs, appear during this stage. The size of the shell at the end of this stage, that is, when the striæ begin to bifurcate, is least in *C. scitulus*, when it is about 2^{mm} long, and greatest in *C. robustus*, where a length of $6\cdot 5^{mm}$ is reached. (See specimens Nos. 1–9, Plate XVI, Row 3; Nos. 1–6, Plate XIV, Row 1; Nos. 1–7, Plate XV, Row 4; Nos. 4, 6, 7, Plate XVII, Row 1.)

Later Neanic and Ephebic Stages.—It would be difficult to make any sharp line which would mark the end of the adolescent period and the assumption of all the adult characters. The size, convexity of valves, and number of striæ continue

* This Journal, vol. xli, 1891, p. 357, pl. xvii, fig. 14.

to increase during these stages, the width becomes greater in proportion to the length, and a number of pairs of spines are added on the cardinal margin.

Gerontic Stage.—Senile characters are not well shown except in *C. mucronatus*. In all, this stage seems to be accompanied by a thickening of the shell, a deepening of the muscle scars, and a growth of the anterior part of the shell, thus reproducing the early neanic conditions of length almost equal to breadth, and an increase in the convexity of the ventral valve.

Strophalosia truncata Hall.

(PLATE XVII, Rows 3, 4.)

Pal. N. Y., iv, 1867, p. 16, pl. 23, figs. 12–24.

Nepionic Shell.—Owing to the deformation of the ventral beak resulting from the method of attachment, very little can be made out concerning that valve in the youngest stages except that it is regularly and moderately convex. The beaks of some of the dorsal valves are extremely well preserved and show well the outlines of the protegulum and nepionic shell. The protegulum is transversely oval, with a gently curved posterior margin. In the best preserved specimen it is ·13^{mm} long and ·155^{mm} wide. The dorsal valve of the nepionic shell is subcircular in outline, with the hinge width about equal to the greatest width below. It is convex on the umbo and often for its whole length, though it is sometimes concave in front. The surface is smooth, without spines (figure 8).

Spines.—After the nepionic stage, spines are developed on both valves, but more numerously on the ventral valve. On the dorsal valve they are generally broken off close to the base. One specimen, however, retains two of the spines, which are long, slender, and lie against the surface of the valve. (See Plate XVII, Row 3, No. 11.) On the ventral valve they are better preserved. They are most abundant along the cardinal margin and stand erect, curving in toward each other from opposite sides of the beak, which suggests that they may have been of use in anchoring the shell. Over the rest of the surface the spines are directed forward.

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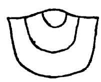

FIGURE 8.—*Strophalosia truncata* Hall; dorsal beak, showing protegulum and nepionic shell. ×16.

Anal Opening.—On the dorsal valve there is a convex chilidium, at the apex of which is the minute anal opening. The inner opening of this tube is at the anterior base of the cardinal process, just in front of the point where it bifurcates. (See Nos. 10 and 12, Row 3.) The cardinal process undergoes considerable change during the life stages. In early neanic stages

it is wider than long, projects little beyond the hinge line, and is divided once. In the adult it is longer than wide, deeply bifurcated in front, and quadrifid on the posterior face. (Compare Nos. 3 and 6, Row 3, with No. 12.)

Tropidoleptus carinatus Conrad.

(PLATE XVIII.)

Pal. N. Y., iv, 1867, p. 407, pl. 62, figs. 2, 3.

Nepionic Shell.—In the nepionic stage, the shell of this species is transversely oval to subcircular, with a hinge width less than the width below. Both valves are convex and smooth. In the early part of this stage the shell is distinctly wider than long, but just before the inception of the plications the length and breadth are about equal.

Changes during Development: Outline.—In the earliest neanic stages the shell becomes longer than wide, and this form is maintained until the shell reaches a length of from 4 to 7^{mm}, after which the width is greater than the length. (Compare the first ten specimens of the series with the last four on Plate XVIII.) From the early neanic through the adult stages the width of the shell at the hinge is greater than the width below, and the cardinal extremities are usually mucronate. In senile stages the width continues to increase without a corresponding growth on the posterior margin, which produces rounded cardinal extremities and gives the shell a transversely elliptical shape.

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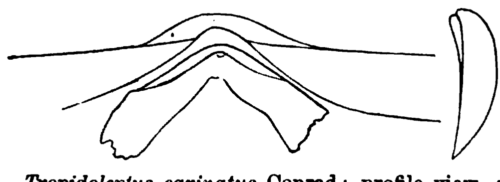


FIGURE 9.—*Tropidoleptus carinatus* Conrad; profile view, showing relative convexity of valves. × 9.
FIGURE 10.—Beaks of another specimen, showing pedicle opening and the wearing away of the ventral beak. × 6.

Convexity of Valves.—Up to a length of from ·75 to 1^{mm} both valves are slightly convex, with the pedicle valve somewhat the deeper. At this point, where the plications generally begin, the brachial valve becomes slightly concave, and continues so through the later stages (figure 9).

Plications.—Immediately after the nepionic stage plications arise on both valves, and apparently several are formed at once. On an individual $1{\cdot}6^{mm}$ in length there are 10 plications on the dorsal valve and 9 on the ventral. New plications

are added at the sides and never implanted, nor do they ordinarily bifurcate. In the adult there are from 17 to 21.

Gerontic Stage.—The senile characters in this species are: Hinge width less than the width below; strong varices of growth numerous; obliteration of the plications toward the front of the shell. The plications become flattened and indistinct toward the front of shells over 20^{mm} long.

Cardinal Process.—The cardinal process is large and prominent. It is joined in front to the bases of the crura and between them is a thickening of the shell, forming a platform which slopes forward to the floor of the valve. (See last figure on Row 3, Plate XVIII.) The posterior face of the process is smooth and rounded, and the lower third is covered by a strong chilidium, which also bounds the posterior ends of the dental sockets. The posterior wall of the cardinal process has, near the top, a narrow, rounded sinus formed by a shelly loop, which is continued forward and downward till it unites with the platform. On either side of this process is a deep conical hole, which extends nearly to the apex of the shell and probably represents the place of attachment of the diductor muscles. (See last figures on Rows 3 and 4, Plate XVIII. The platform has been broken away from the specimen at the end of Row 4, but the loop in the middle of the process and the two holes are well shown.)

Directly in front of the loop is a groove in the platform leading back to a minute anal tube, which runs along the middle line of the process and has its external opening in a pore just at the point where the chilidium meets the apex of the valve.

Trigeria lepida Hall.

Pal. N. Y., viii, pt. 2, 1893, p. 274, pl. 50, figs. 36–40.

Description of Smallest Specimen.—The smallest individual of this species is roughly triangular in outline, the rostrate beak, which projects $\cdot 25^{mm}$ beyond the hinge, forming the apex. The ventral valve is convex and smooth, without fold or sinus. The delthyrium is narrow and open. The dorsal valve is convex, and has a deep, narrow median sinus. The length of this shell is $1\cdot 09^{mm}$ and the width $\cdot 93^{mm}$. This form is very suggestive of the adult *Centronella* (figure 11).

11

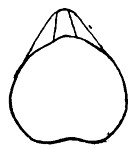


FIGURE 11.—*Trigeria lepida* Hall; young individual, before the inception of plications. ×16.

In the older specimens the beak is less prominent and in specimens more than $3\cdot 5^{mm}$ long the dorsal sinus becomes obliterated and both valves are convex. Shells more than

$1·5^{mm}$ long have plications, the number increasing from 7 on a specimen of that length to about 18 on a specimen $5·5^{mm}$ long.

12

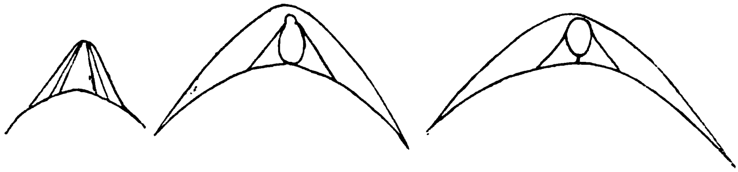


FIGURE 12.—*Trigeria lepida* Hall; series showing the growth of the deltidial plates and the encroachment of the pedicle upon the ventral beak. ×8.

Deltidial Plates.—None of the specimens less than 3^{mm} long show any deltidial plates. In succeeding stages the plates appear as narrow triangles, one on each side of the delthyrium, and these triangles gradually become broader until they meet at the base. In the meantime, the pedicle encroaches upon the ventral beak so that an oval pedicle opening is formed in the adult (figure 12).

Eunella Lincklaeni Hall.

Pal. N. Y., iv, 1867, p. 397, pl. 60, figs. 49–65.

The list of changes in the form of this shell is not complete enough to offer anything new, but there are one or two interesting points in connection with the species.

Punctæ.—On the dorsal beak of the smallest shell ($1·17^{mm} \times ·84^{mm}$) the first punctæ can be seen, and their arrangement agrees with that seen on the nepionic shell of *Terebratulina septentrionalis.** The first pair of punctæ is $·07^{mm}$ from the

13 14 15

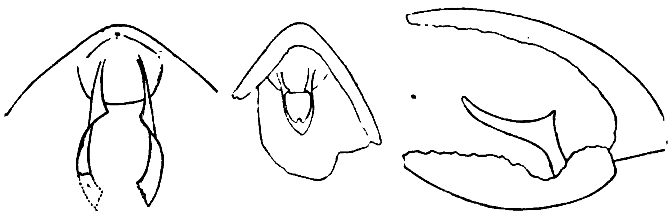


FIGURE 13.—*Eunella Lincklaeni* Hall; part of the loop of an adult specimen. ×8.
FIGURE 14.—Centronelliform stage of the loop. ×8.
FIGURE 15.—Side view of specimen shown in Figure 14; shell broken away to show the loop. ×16.

beak, and in front of them, on the median line, is a third one. Beyond this they are scattered sparingly over the surface for a

* E. S. Morse, Memoirs Boston Soc. Nat. Hist., vol. v, No. 8, 1902, pl. 62, fig. 15: also vol. ii, pt. i, No. 2, pl. 1, fig. 3.

short distance, but toward the front of the shell they become very numerous.

Brachidium.—The smallest specimen retaining the brachidium, and the only one in which the loop is complete, is about 4^{mm} in length. The loop extends about half-way to the front of the valve. The primary lamellæ run sharply upward and forward, and the anterior portions run about parallel to the floor of the valve, meeting at the front in an acute angle. As the two lamellæ approach each other they become wider, and, where they join, there is also a point directed backward (figures 14, 15). This is evidently an immature condition of the loop and differs greatly from the loop of the adult of this species. It agrees with the centronelliform stage of loop as described by Beecher and Schuchert.* This is the second genus of brachiopods in which this stage of loop has been observed, and its presence serves to confirm the view expressed in the paper referred to, that the *Centronella* form of loop is a primitive one for this superfamily of brachiopods. It differs slightly from the loop of *Dielasma turgida*† in that the lamellæ are narrower and the angle in front is less acuminate.

Cyrtina hamiltonensis Hall.

(Plate XV, Row 6.)

Pal. N. Y., iv, 1867, p. 268, pl. 27, figs. 1–4; pl. 44, figs. 26–33, 38–52.

Nepionic Stage.—The smallest individual in the collection represents this species in the nepionic stage. The shell is nearly circular in outline, and the length and breadth are the same,— $\cdot 53^{mm}$ (figure 16). The hinge line is $\cdot 32^{mm}$ long and

16 17 18 19

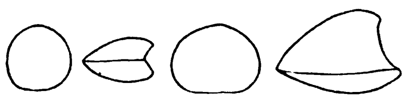


Figure 16.—*Cyrtina hamiltonensis* Hall; outline of the smallest specimen. ×28.
Figure 17.—A larger specimen; profile. ×16.
Figure 18.—The same; outline. ×16.
Figure 19.—A slightly older individual, showing the rapid change in the relative convexity of the valves. ×16.

nearly straight. The beaks of the two valves are elevated above the hinge line, and between them is the pedicle opening, which is shared by both valves. The valves are subequally convex and smooth, with no trace of fold or sinus (figures 17, 18).

* Proceedings Biol. Soc. Washington, vol. viii, p. 73, pl. x, fig. 1.
† Loc. cit.

Changes during Development: Convexity of Valves.—When the individuals become about ·75^{mm} in length the valves are still nearly equally convex, and the ventral area is curved and inclined backward, so that the beak of that valve projects beyond the beak of the dorsal valve. In stages but little later, when the shell is slightly over 1^{mm} in length, the ventral valve is four or five times as deep as the dorsal, and the ventral area becomes more erect, so that the beak is anterior to the hinge line.

Plications.—When the shell has reached a length of from ·45 to ·60^{mm} a sinus is formed in the ventral valve and very soon after its initiation a fold is produced in the opposite shell. This stage, in which there is no other ornamentation than the fold and sinus, continues for some time. The largest specimen showing this state is 1·5^{mm} long and 2·26^{mm} wide. Shells at this period are almost globular and difficult to separate from the young of *Ambocœlia umbonata* unless carefully examined. (See No. 1, Row 6, Plate XV.)

The plications are introduced in pairs on the lateral margins, each pair coming in outside the older ones.

Spirifer mucronatus Conrad.

(Plate XVI, Rows 1, 2.)

Pal. N. Y., iv, 1867, p. 216, pl. 34, figs. 1–32.

Delthyris consobrinus d'Orbigny.

Pal. N. Y., iv, 1867, p. 222, pl. 35, figs. 15–23.

As the development of these two species is practically the same, they will be considered together.

20

Figure 20. — *Spirifer mucronatus* Conrad; outline of protegulum and shell in nepionic stage; taken from a dorsal valve. ×28.

Protegulum.—On the beak of a well-preserved dorsal valve of *S. mucronatus* is the impression of the initial shell. It is circular, somewhat convex, with a curved hinge. The diameter is ·11^{mm} (figure 20).

Nepionic Shell.—In the nepionic stage the shell is oval in outline, and broader than long. Both valves are convex, the ventral a little the deeper. The hinge width is less than the greatest width below. The surface is smooth, with no fold, sinus, or plications.

Neanic Stages.—In the earliest neanic stages a sinus is developed in the ventral valve, bounded by two strong ridges, which are the first plications. Following this a fold is formed in the dorsal valve and plications are added on the margins in pairs, each pair coming in outside the older ones. The later plications do not reach the beak.

In an early neanic stage the hinge width is the greatest width of the shell, the cardinal extremities soon become acuminate, and nearly all adolescent shells more than 5 or 6^{mm} wide are strongly mucronate. (Compare the first three shells of the series on Plate XVI with the older ones; also observe the growth lines on specimen No. 3, Row 2.)

It is interesting to note that in their early neanic stages these transversely elongated Devonian Spirifers pass through forms which correspond to the adult condition of certain Niagara species. The adult of *Spirifer crispus*, with a fold and 8 plications on the dorsal valve, and a hinge width nearly equal to the width below, corresponds very closely in these particulars, and in its index, with a specimen of *Spirifer mucronatus* about 2^{mm} long, and, except in the number of plications, with the specimen of *Delthyris consobrinus* 1^{mm} long.

Spirifer radiatus, with no plications, the width only one-seventh greater than the length, and the width at the hinge less than the width below, corresponds to a still earlier stage in the development of the present species.

Summary.

The foregoing descriptions show that the general deductions which have been previously drawn as to the character of the nepionic shell, the development of the pedicle tube and the deltidial plates, and the acquirement of surface characters, hold good in the families here studied for the first time. Other general facts will be noted under the families.

Centronellidæ.—The shape of *Trigeria lepida* in the nepionic stage is almost exactly that of adult *Centronella*, and thus another bit of evidence is added to that afforded by the loop, showing its relation to the Centronellidæ rather than to the Terebratulidæ. Going back to the very earliest stage, before the development of the dorsal sinus, the shell has characters common to the superfamily, that is, a biconvex shell with the ventral beak extended beyond that of the dorsal valve.

Terebratulidæ.—*Eunella*, in its early stages, is a rather simple, generalized type of shell, not differing greatly from the very youngest stage of *Trigeria*, but the development of its loop shows progress beyond the centronelliform stage. The position of the first three punctæ, which is the same as that in the recent genus *Terebratulina*, is interesting.

Terebratellidæ.—The evidence that *Tropidoleptus* belongs to this family has not been strengthened or diminished by the present studies. It still rests on the form of the loop as described by Hall, and later verified by Hall and Clarke. The development is similar to that of the Strophomenidæ, and the

articulation is like that in *Chonetes.* No deltidial plates are developed, and the pedicle is probably functional throughout life. The cardinal process is very large, and of a peculiar type, quite different from that of any of the Strophomenidæ.

Spiriferidæ.—The marked difference in shape and relative convexity of valves of *Cyrtina* in the early neanic stage, from *Spirifer* and *Delthyris* in the same stage, together with the geological range, would seem to indicate that, while both may be derived from the same ancestral stock, *Cyrtina* is not a modified *Spirifer*. *Delthyris*, *Spirifer*, *Ambocœlia*, and *Cyrtina* all start out with an equivalve nepionic shell and a pedicle opening shared by both valves. But with the first changes in later nepionic and early neanic stages, when the fold and sinus appear, *Cyrtina* and *Ambocœlia* become strongly inequivalve, while in *Spirifer* and *Delthyris* the valves retain for a short time their equality of convexity. In other words, the generic habit is assumed immediately after leaving the form that is common to all the members of the superfamily, and *Cyrtina* passes through no *Spirifer*-like stage.

Spirifer and *Delthyris* are so exactly alike in their external form in the youngest neanic stages that it is impossible to separate them.

Strophomenidæ.—The biconvex nepionic shells of *Stropheodonta*, with a median dorsal fold and ventral sinus (which may or may not be present), and the similar nepionic shells of *Chonetes* indicate a possible common origin in some shell of the *Triplecia* type, though not perhaps in that genus which thus far has not been found below the Calciferous, while *Rafinesquina*, which would seem to be the immediate ancestor of *Stropheodonta*, extends into the Chazy and probably lower, without any marked change in form. The early neanic stages of *Stropheodonta*, before the appearance of the crenulations on the hinge margin, are very similar to the adult *Rafinesquina*.

An interesting feature in the development of *Stropheodonta* is the marked mucronation of the cardinal extremities of the adolescent specimens. This mucronation disappears to a greater or less extent in the older stages. This same thing is noticed in *Spirifer*, and there many of the adults retain the mucronate forms, but they are only a phase in the life of the genus. In the ontogeny the outline changes from rounded forms in the nepionic and early neanic stages, through a mucronate form in the later neanic, and back to a rounded form in the adult or senile condition. The same things occur in the phylogeny of *Spirifer*, at least, for there are Niagara species with rounded cardinal extremities, then a great development of the mucronate types in the Lower and Middle Devonian, and a return to the rounded forms in the Carboniferous. A similar change is seen in *Platystrophia*.

The difference between the varieties *pectinacea* and *arctistriatus* of *Orthothetes chemungensis* is a good example of the effect of acceleration in the development of certain characters. The steps in the development of the two are exactly the same, but because the striæ are introduced at an earlier stage on one than on the other, the shells differ greatly in appearance.

Productidæ.—The facts in the development of *Chonetes* do not seem to support the idea put forward by Hall and Clarke that *Chonetes* might be descended from *Plectambonites*, a shell which in many respects much resembles *Chonetes*. The early neanic stages have an outline which is much the same as that of *Rafinesquina* and *Stropheodonta*. The resemblance of the nepionic shell to *Triplecia* has already been referred to, and this, with the other characters, relates the shell to the Strophomenidæ. It is clearly a transition form between the latter family and the Productidæ.

Paleontological Laboratory,
Yale University Museum,
January 6, 1904.

EXPLANATION OF PLATES.*

Plate XII.

Pholidops oblata Hall.

Rows 1 and 2.—Series of dorsal valves. × 2.
Rows 3 and 4.—Series of ventral valves. × 2.

Plate XIII.

Row 1.—Partial series of *Stropheodonta perplana* Conrad; ventral valves. Specimens Nos. 8—9 show well the mucronate cardinal extremities of the adolescent individuals.

Rows 2–4.—Series of *Stropheodonta inæquistriata* Conrad; ventral valves, showing the shells in neanic, ephebic, and gerontic stages.

Plate XIV.

Chonetes scitulus Hall.

Rows 1 and 2.—Series of ventral valves. ×2.
Rows 3 and 4.—Series of dorsal valves: interior view. ×2.
Specimens Nos. 1 and 2 of Row 1, and Nos. 1 and 2 of Row 3, show the ventral sinus and dorsal fold of the very young stages. Most of the specimens in Row 4 show the brachial scars.

Plate XV.

Row 1.—Partial series of *Orthothetes chemungensis* var. *pectinacea* Hall; dorsal valves. ×2.

Row 2.—Partial series of *Orthothetes chemungensis* var. *arctistriatus* Hall; dorsal valves. ×2.

* Unless otherwise stated, the figures are natural size.

Row 3.—Partial series of *Orthothetes bellulus* Clarke; dorsal valves. ×2.
Rows 4 and 5.—Series of *Chonetes mucronatus* Hall; ventral and dorsal valves. ×2.
Row 6.—Series of *Cyrtina hamiltonensis* Hall; dorsal valves. ×2.

Plate XVI.

Rows 1 and 2.—Partial series of *Spirifer mucronatus* Conrad; dorsal valves.
Row 3.—Series of *Chonetes coronatus* Conrad; ventral valves, exterior.
Row 4.—The same; dorsal valves, interior.

Plate XVII.

Rows 1 and 2.—Series of *Chonetes robustus* Raymond; ventral and dorsal valves. ×2.
Rows 3 and 4.—Series of *Strophalosia truncata* Hall; dorsal and ventral valves. ×2.

Plate XVIII.

Tropidoleptus carinatus Conrad.

Rows 1 and 2.—Series of ventral valves.
Rows 3 and 4.—Series of dorsal valves.

ART. XXVII.—*Studies in the Cyperaceæ;* by THEO. HOLM. XXI. New or little known species of *Carex.* (With figures in the text, drawn by the author.)

Carex neurochlæna sp. n. (figs. 1–2).

RHIZOME slender, ascending, stoloniferous, the leafsheaths persisting, light brown; leaves shorter than the culms, very narrow, carinate, scabrous; culms up till 24^{cm} in height, curved, almost capillary, trigonous, scabrous below the inflorescence, otherwise glabrous, phyllopodic; spikes two to four, gynæcandrous or the lowest one sometimes purely pistillate (fig. 1), small and few-flowered, roundish, contiguous or the lowest one remote, reddish brown, the bracts inconspicuous or the lowest one with a filiform blade much shorter than the inflorescence; scales broadly ovate, those of the staminate flowers acute, the others obtuse, reddish brown with green midrib and hyaline margins; perigynium (fig. 2) longer, but narrower than the scale, sessile, slightly spreading, broadly elliptical, attenuated at both ends, plano-convex, wingless, prominently nerved, greenish, the beak short, slit on the convex face; stigmata two.

Collected above Rink rapids, Yukon River in Yukon, by Professor John Macoun (No. 53,879).

This species belongs to the *Neurochlænæ.*

Carex vagans sp. n.

Rhizome horizontally creeping, forming dense mats, the leaf-sheaths persisting, light brown; leaves glaucous, shorter than the culms, very narrow, carinate, scabrous; culms numerous, from 20 to 30^{cm} in height, very slender and weak, triangular, scabrous, phyllopodic; spikes three to five, androgynous or the lateral purely pistillate, small and few-flowered, sessile, forming an interrupted, spicate inflorescence about 2^{cm} in length, the bracts short and inconspicuous; scales ovate, acute, reddish brown with green, broad midrib and hyaline margins, shorter than the perigynium; perigynium sessile, somewhat spreading at maturity, ovoid, plano-convex, wingless, two-ribbed (the marginal), light brown, minutely scabrous along the very short beak, deeply slit on the convex face; stigmata two.

Collected in Oregon: Steins Mts., flat opposite Andrews, alt. 1950^{m}, by Mr. John B. Leiberg (No. 2558).

In aspect much like *C. occidentalis* Bail., but in this the spikes are more dense-flowered, the perigynium elliptical, stipitate, spongious at the base and the beak prominently bidentate.

Carex phæolepis sp. n.

Rhizome short, creeping, the leaf-sheaths persisting, light brown; leaves light green, a little shorter than the culms, narrow, but flat, scabrous; culms not numerous, from 25 to 35^{cm} in height, slender, but stiff, erect, triangular, scabrous, phyllopodic; spikes four to eight, androgynous and the staminate portion very prominent in all of these, ovate, rather small, sessile and contiguous or the lower ones remote, the bracts inconspicuous; scales ovate-lanceolate, mucronate, light brown with broad hyaline margins and greenish midvein, longer than the perigynium; perigynium almost sessile, erect, broadly elliptical, plano-convex, wingless, two-ribbed (the marginal), colorless, minutely scabrous along the short beak, which is slit on the convex face; stigmata two.

Collected in Eastern Oregon: Bear Butte, Crook County, alt. 1710^{m}, by Mr. John B. Leiberg (No. 335).

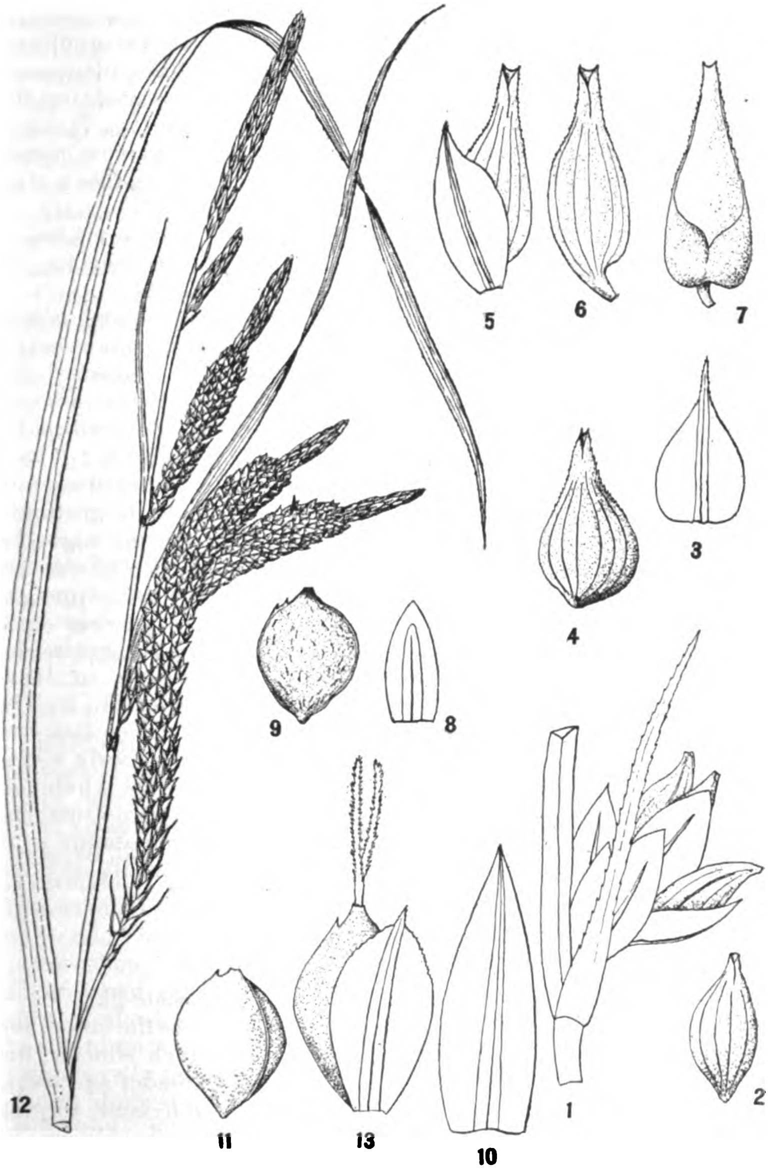
Carex chrysoleuca sp. n. (figs. 3–4).

Rhizome wanting, but apparently cæspitose, the leaf-sheaths fibrillose, light brown; leaves light green, about half as long as the culms, narrow, carinate, scabrous; culms from 40 to 55^{cm} in height, stiff, erect, trigonous, scabrous near the inflorescence, otherwise glabrous, phyllopodic; spikes about twenty, the lowest ones decompound, androgynous and the staminate portion very prominent, ovate, small in comparison to the size of the plant, sessile and contiguous, the bracts inconspicuous or the lowest one sometimes elongated, setiform; scales of staminate flowers lanceolate, sharply pointed, hyaline to light yellowish brown, those of the pistillate flowers (fig. 3) ovate with the midvein extended into a conspicuous awn, hyaline to yellowish, shorter than the perigynium; perigynium (fig. 4) sessile, erect or slightly spreading, broadly ovate, plano-convex, wingless, prominently several-nerved on convex face, light brown or greenish, scabrous along the distinct beak, which is deeply slit on the convex face; stigmata two.

Collected near Mariposa, California, by Mr. J. W. Congdon.

Carex vitrea sp. n. (figs. 5–7).

Rhizome wanting, but apparently cæspitose, the leaf-sheaths persisting, light brown; leaves glaucous, longer than the culms, narrow, flat, very scabrous; culms from 60 to 65^{cm} in height, slender, triangular, scabrous, phyllopodic; spikes numerous, decompound, forming an interrupted spicate inflorescence, up till 8^{cm} in length, androgynous, the staminate portion very prominent, sessile, the lower bracts setiform, short; scales of



Carex neurochlæna, figs. 1–2; *C. chrysoleuca*, figs. 3–4; *C. vitrea*, figs. 5–7; *C. dives*, figs. 8–9: *C. Schottii*, figs. 10–11; *C. lacunarum*, figs. 12–13. (Explanation in text.) The figures 1–11 and 13 are magnified; fig. 12 represents the natural size.

staminate flowers lanceolate, mucronate, hyaline with green midvein, those of the pistillate flowers (fig. 5) ovate, acuminate and mucronate, hyaline, much shorter than the perigynium; perigynium stipitate, nearly erect, ovate-lanceolate, plano-convex, spongious at the base, wingless, several-nerved on the convex (figs. 5–6), nerveless on the plane face (fig. 7), light green to almost hyaline, scabrous along the narrow beak, which is emarginate and deeply slit on the convex face; stigmata two.

Collected at Palm Springs (Agua Caliente), desert base of San Jacinto Mountain, at an elevation of 500–700 ft., in Southern California, by Mr. S. B. Parish (No. 4144).

The last three species: *C. phæolepis*, *chrysoleuca* and *vitrea* are characteristic by the staminate portion of their spikes being very prominent, and by this character they are readily distinguished from all other members of the *Acanthophoræ*. However, there is a fourth species "*C. vallicola*" described by Dewey* which is said to exhibit the same peculiarity: "having the staminate part of the spikelet a short projecting column or cylinder at the apex, often longer than the pistillate part," and we thought at first that one of our species might be identical with this. But the perigynium of *C. vallicola* is described as "obovate, tapering below, rostrate and stiped, at the orifice oblique," besides "being nerveless," thus showing a marked distinction from the structure of the perigynia possessed by our species. Dewey's plant was collected in Jackson's Hole, on Snake River, at an elevation of 6000 ft., by Dr. F. V. Hayden, but the specimens which the writer has had the opportunity to examine, were so young and poorly represented, that they gave no illustration of the species whatever, and as we have learned from Mr. Clarke, there is no material of it in the Kew Herbarium. So far, *C. vallicola* stands as an imperfectly known species, but is evidently a near ally of those three, described above.

Carex venustula sp. n.

Rhizome matted with short stolons, the scale-like leaves brown, becoming fibrillose; basal leaves as long as the culm, narrow and flat, slightly scabrous, the cauline much shorter, but with long sheaths; culm about 42^{cm} in height, slender and weak, triangular, scabrous, aphyllopodic; spikes three to four, the terminal staminate, clavate, the lateral pistillate or the uppermost sometimes androgynous, contiguous, all borne on filiform peduncles, drooping, short and dense-flowered, subtended by sheathing bracts, of which the lowest one has a blade about as long

* This Journal, II, vol. xxxii, 1861, p. 40.

as the inflorescence; scale of staminate flower oblong, obtuse, reddish brown with green, not excurrent, midvein; scale of pistillate flower spathulate oblong, obtuse to aristate, deep purplish to almost black with the midvein obsolete, narrower than the perigynium; perigynium stipitate, erect, elliptical oblong, minutely granular above, two-nerved, pale green with purplish spots above, the beak short, emarginate; stigmata three or, sometimes, two, the style not exserted.

Alaska: Chistachina River, lat. 63, between Cook inlet and the Tanana River, collected by Captain E. F. Glenn, and British Columbia: Glacier, alt. 4122 ft., by Zoë W. Palmer.

Carex venustula is a near ally of *C. Montanensis* Bail., although it would not seem so if we compare the diagnoses alone. For it is hard to understand how specimens of authentically determined *C. Montanensis* can be described as belonging "to the Rigidæ, being allied to *C. Tolmiei*, yet having the habit of *C. Magellanica*." The diagnosis* is very incomplete and in several points incorrect. However, the main distinction between the two depends especially upon the structure of the scales and the perigynium: the former being about as long as the very broadly elliptical perigynium in *C. Montanensis*, while in the other species the scales, obtuse to aristate, are much shorter than the elliptical oblong perigynium. Common to both are the long-peduncled drooping spikes of dark color, the short stem-leaves and aphyllopodic culms.

Carex microchæta sp. n.

Rhizome stoloniferous with persisting, brownish scale-like leaves; leaves shorter than the culm, broad, flat and scabrous along the revolute margins; culm from 10 to 20^{cm} in height, erect, coarse and stiff, triangular, scabrous, phyllopodic; spikes three to four, the terminal and, sometimes, the uppermost lateral staminate, the others pistillate, contiguous, erect, sessile, or the lowest one shortly peduncled, all short, thick and dense-flowered, subtended by sheathing bracts with the blades shorter than the inflorescence; scales of staminate and pistillate flowers, elliptical oblong, acuminate, purplish black with pale midvein extended into a short, scabrous awn, longer but narrower than the perigynium; perigynium stipitate, erect, elliptical, granular, two-nerved, purplish spotted above, whitish below, the beak short, bifid; stigmata three, the style exserted.

Yukon: Klondike, Indian Divide, collected by Professor John Macoun (No. 53,877).

The affinity is with *C. Tolmiei* and *C. spectabilis* of the *Melananthæ*.

* Botanical Gazette, 1892, p. 152.

Carex spectabilis Dew.*

This species, although well defined by Dewey (l. c.), has been overlooked by several authors and has been described as new "*C. invisa* Bailey," or confounded with various other species, for instance, with *C. macrochæta* Mey. var. *pseudopodocarpa* Kükthl., and *C. podocarpa* R. Br. We can add nothing to the diagnosis except that the culm is aphyllopodic, and that the scale-like leaves of the densely matted rhizome become fibrillose. It is said to have been originally collected in "the Arctic Region," but since then it has been found in several places in the mountains of British Columbia, Washington and California. In regard to *C. podocarpa* R. Br. we might state that Mr. C. B. Clarke has informed us that a careful examination of Robert Brown's specimen has convinced him that it is merely a young specimen of *C. rariflora* Sm.

Carex vulgaris Fr.

This plant offers an excellent example of a species distributed over a wide geographical area and possessed of great plasticity in respect to variation throughout the northern hemisphere. And so numerous are the varieties that Fries thought it would require a book to enumerate and describe them all; moreover, the variation is expressed in quite a distinct way wherever the plant occurs, in northern Europe or in the northwestern parts of this continent, where the species appears to be best represented. The species was already known to Tournefort and Ray as "*Cyperoides*" and "*Gramen*," while Linnæus was the first to describe it as a "Carex": *nigra verna vulgaris* (Flora Lapponica No. 330). Since then it has been described as *C. Goodenoughii* by Gay; a name, however, that only applies to the variety "*stolonifera*," while the typical form, as it occurs in Lapland, has received the name "*vulgaris*" by Elias Fries (Mant., III, p. 153). The plant is so well known and so well described that it is not necessary to reproduce the diagnosis *in toto* for the sake of illustrating the species as it occurs on this continent, but we might quote a few words about the structure of the perigynium. This organ is by Fries (l. c.) described as being subsessile, persisting, roundish-elliptical, many-nerved and longer than the obtuse scales; that the perigynium, sometimes, is nerveless, is evident from the description in Hartman's Flora of Scandinavia (11th edit.). If we now examine some of the most characteristic European varieties, Danish, Norwegian, Swedish and German specimens for instance, the perigynium appears with an outline of from roundish to very narrow elliptical, with a short stipe or strictly

* This Journal, vol. xxix, p. 248, 1836.

sessile, with the surface granular to densely verrucose, with or without a few spinulose projections along the upper margins, with the orifice of the short beak wholly glabrous or minutely spinulose, and finally with many very prominent nerves, with only a few and quite faint or apparently with none at all, the two marginal nerves being usually obsolete. Accompanying these perigynial structures a pronounced variation in habit occurs: in respect to the rhizome, the relative position of the pistillate spikes, the length of the peduncles, the length of the spikes, of the bracts, etc., distinctions that have proved to be sufficiently valid for establishing a number of varieties, especially in Northern Europe. Among these are, for instance, "*tornata* Fr.," which is densely cæspitose, with thick, rigid culms, broad leaves and heavy spikes, "*juncea* Fr.," a very slender form with convolute, filiform leaves and remote spikes, "*stolonifera* (Hoppe)" with long stolons and short, curved culms, "*longe pedunculata* Blytt" with the culms, tall, nodding at the apex and with long-peduncled, dark spikes of which the scales are acute and longer than the perigynia, "*rigida* Blytt" which grows in dense tufts and of which the culms and leaves are very stiff and scabrous, besides the pistillate spikes are very long, linear and often androgynous, "*atra* Blytt" with slender culms, and black, sessile spikes, mostly in a dense head, and "*anomala* Blytt" with the terminal spike gynæcandrous. By studying the species as it is represented in this country, we have seen the typical *C. vulgaris* from Alaska, Colorado, Cape Breton Island and Nantucket, Massachusetts, while the var. *stolonifera* has been collected in Labrador. It appears, however, as if the species is best represented in the northwestern parts of this continent — Alaska and Yukon, where certain varieties have been collected in large quantities and at several stations. Of these we propose as new

var. *limnophila* nob.

Rhizome densely cæspitose; culms curved, only about 10^{cm} in length; spikes very short and thick, sessile and contiguous, almost capitate, the terminal mostly gynæcandrous; perigynium stipitate, elliptical, denticulate near the beak, purplish spotted above.

Collected on St. Paul Island, Bering Sea, growing in mud by marshes. Mr. James M. Macoun (No. 16,613); also on a nunatak in Columbia glacier, Prince William's Sound, by Messrs. Coville and Kearney (No. 1365).

This variety bears a strong resemblance to *C. rufina* Drej., from which it differs only in its more robust habit and the

structure of the perigynium. However, it is interesting to see that some Scandinavian authors are inclined to consider *C. rufina* as a reduced form of *C. vulgaris.*

var. *hydrophila* nob.

Rhizome very slender, stoloniferous, the scale-like leaves persisting, shining, purplish brown; leaves about as long as the very slender culms, narrow but flat; spikes cylindrical, dense-flowered, peduncled, erect or somewhat spreading; perigynium prominently stipitate, roundish-elliptical, wholly glabrous and nerveless.

Yukon: in water, Colorado Creek, collected by Professor John Macoun (No 53,843).

var. *lipocarpa* nob.

Rhizome densely cæspitose with persisting, light brown sheaths; leaves glaucous, narrow but flat as long as the culms; culms from 15 to 40^{cm} in height, slender, but erect; spikes long and very dense-flowered except towards the base, more or less peduncled, especially the lowest one, which is often developed from near the base of the culm and branched; bracts foliaceous and quite long; perigynium with a long stipe, elliptical, glabrous, many-nerved, the beak very distinct and proportionately long.

Collected in Alaska at several stations, on Vancouver Island, in the Selkirk Mountains, British Columbia, and in the Chilliwack Valley, by Mr. James M. Macoun and others.

The fact that the perigynium is early deciduous in this variety has led several authors to the belief that it is identical with the South American *C. decidua* Boott, but the terminal spike is, in this species, nearly always gynæcandrous and the perigynium is oblong-ovate, denticulate-serrate.

Some of the specimens from Alaska were sent to Mr. C. B. Clarke of Kew, who kindly informed the writer that these were identical with Scouler's Columbia River plant, which Boott first named *C. decidua,* but afterwards corrected to *C. vulgaris* Fr.

The so-called *C. interrupta* Bcklr. var. *impressa* Bailey is, also, according to Mr. Clarke, a form of *C. vulgaris*, and almost like the typical plant.

var. *elatior* Lang.

Rhizome cæspitose; culms and leaves until 55^{cm} in length, very slender; spikes sessile, cylindrical and dense-flowered, some

what remote, subtended by short, filiform bracts; perigynium elliptical, stipitate, many-nerved, glabrous.

Nova Scotia: Halifax, collected by Professor John Macoun (No. 16,678). The specimens were identified as var. *strictæformis* Bail., but they do not differ in any way from our European material, although the nerves of the perigynium are not always as prominent as in the American plant.

In comparing these North American varieties of *Carex vulgaris* with the European, we notice as a prominent feature for distinguishing these the strong development of the stipe in the former, and sometimes to such an extent as making the perigynia early deciduous. In the European forms the stipe is often very distinct, but seldom as long and slender as in the American. In regard to the nervation, the perigynium shows, as already stated, several variations, and a prominently many-nerved perigynium seems to be the most frequent among the representatives in this country.

The beak is, as a rule, very short in all European specimens, also in the American with the exception of the var. *lipocarpa*, where it is quite prominent.

There is, still, another plant which may belong here, but of which the writer has only studied a scant supply of material. This is *C. Kelloggii* W. Boott, which seems very near the typical *C. vulgaris*, by the very short beak and stipe of the perigynium.

Carex sphacelata sp. n.

Rhizome ascending, stoloniferous with persisting, deep reddish brown scale-like leaves; leaves about as long as the culm, rather broad and flat, glabrous; culm from 30 to 40^{cm} in height, erect, stiff, triangular, glabrous, phyllopodic; spikes three to five, the terminal and, sometimes, the uppermost lateral staminate, the others pistillate, contiguous or the lower ones remote, sessile or short-peduncled, erect, dense-flowered, subtended by foliaceous, sheathless bracts with the blades broad and longer than the inflorescence; scale of staminate flower linear-lanceolate, obtuse, deep brown with pale midrib; scale of pistillate flower ovate-lanceolate, almost black with the midvein obsolete, shorter and much narrower than the perigynium; perigynium stipitate, erect, broadly elliptical, granular, two-nerved, purplish-spotted above, whitish below, the beak short, entire; stigmata two, the style enclosed.

Collected in Yukon: Colorado Creek, by Professor John Macoun (No. 53,847).

This species may be placed near *C. aquatilis* Wahl.

Carex chionophila sp. n.

Rhizome cæspitose with persisting, brown leaf-sheaths; leaves longer than the culm, narrow but flat, scabrous; culm from 30 to 40^{cm} in height, erect, slender, trigonous, scabrous, phyllopodic; spikes four to five, the terminal staminate, the lateral pistillate or with a few staminate flowers at the apex, contiguous, sessile or the lowest one peduncled, erect, dense-flowered, cylindric and until 4^{cm} in length, subtended by sheathless bracts with blades about as long as the inflorescence; scale of staminate flower oblong, obtuse, purplish with pale midvein; scale of pistillate flower ovate-oblong, obtuse, black with pale midvein, shorter and much narrower than the perigynium; perigynium minutely stipitate, erect, pyriform, granular above, nerveless, light green above, whitish below, the beak very short, entire; stigmata two or three.

Collected in a brook, West Dawson, Yukon, by Professor John Macoun (No. 53,849).

Allied to *C. sphacelata* but is readily distinguished by the characters enumerated above; it is altogether a more graceful plant with slender culms and narrower leaves, besides of a much lighter color.

Carex consimilis sp. n.

Rhizome horizontal, stoloniferous with persisting light brown scale-like leaves; leaves about as long as the culm, narrow with revolute margins, scabrous; culm about 25^{cm} in height, erect, stiff, triangular and scabrous, phyllopodic; spikes four, the terminal staminate, the lateral pistillate or sometimes androgynous, contiguous, sessile or the lowest one short-peduncled, erect, subtended by very short, sheathless bracts; scale of staminate flower linear-lanceolate, light brown; scale of pistillate flower ovate-lanceolate, acute to obtuse, black with the midvein obsolete, longer, but narrower than the perigynium; perigynium minutely stipitate, erect, orbicular, granular above and sharply denticulate along the upper margins, two-nerved, purplish spotted above, light brownish green below, the beak short, entire; stigmata two, style short but exserted.

Collected near Klondike, Indian Divide, Yukon, by Professor John Macoun (No. 53,878).

In habit not unlike *C. hyperborea* Drej., but the perigynium is very different.

Carex cyclocarpa sp. n.

Rhizome stoloniferous with persisting, purplish scale-like leaves; leaves shorter than the culm, flat, but narrow; culms from 12 to 42^{cm} in height, slender, but erect, or slightly curved,

triangular, scabrous, phyllopodic; spikes three to four, the terminal staminate, the lateral pistillate or, sometimes, the upper one androgynous, contiguous, sessile or the lowest one peduncled, erect, dense-flowered, short, subtended by bracts, of which only the lowermost is foliaceous, shorter than the spike and with black auricles; scale of staminate flower linear-lanceolate, brown with pale midvein; scale of pistillate flower ovate, obtuse, black with the midvein obsolete, shorter and much narrower than the perigynium; perigynium shortly stipitate, erect, turgid, nearly globose, granular, two-nerved, brownish green with purplish spots above, the beak minute, entire; stigmata two or three, the style exserted.

Grows in tufts in woods and in boggy places: West Dawson, mountains back of Dawson, Hunker Creek, Yukon, collected by Professor John Macoun (Nos. 53,842, 53, 55, and 58). This together with the preceding, *C. consimilis*, are no doubt close allies, but they appear so distinct from the other *Microrhynchæ*, that their place within the section seems uncertain. In some respects they resemble *C. vulgaris* and *C. rigida*, in others *C. cæspitosa* and *C. lugens*, yet they may "ad interim" be placed with *C. nudata* between *C. aquatilis* and *C. interrupta*, as indicated in "Greges Caricum."

Carex limnocharis sp. n.

Rhizome stoloniferous with persisting, purplish scale-like leaves; leaves as long as the culm, rather narrow, flat, scabrous; culm 30^{cm} in height, erect, but curved at the apex, triangular, glabrous, phyllopodic; spikes five, the terminal staminate, the lateral pistillate or the uppermost androgynous, contiguous, peduncled, spreading, not very dense-flowered, about 5^{cm} in length, but thin, subtended by sheathless, foliaceous bracts, much longer than the inflorescence; scale of staminate flower linear-lanceolate, acute, light brown; scale of pistillate flower ovate acuminate, reddish brown with green, not excurrent midrib, narrower but longer than the perigynium; perigynium stipitate, erect, broadly elliptical, granular above, nerveless, pale green, the beak short, entire; stigmata two, style enclosed.

In muddy places, Klondike River, Yukon, collected by Professor John Macoun (53,846).

Allied to *C. acutina*, but more robust; a beautiful species with long, slender spikes of reddish brown color, in habit much like the European *C. prolixa* Fr.

Carex millegrana sp. n.

Rhizome wanting, but apparently cæspitose with persisting reddish-brown leaf-sheaths: leaves shorter than the culm, nar-

row, but flat, scabrous; culms until 60^{cm} in height, slender, triangular, scabrous, phyllopodic; spikes five to six, the terminal staminate, the lateral pistillate or the uppermost androgynous, contiguous, nearly sessile, spreading to almost drooping, from 4 to 8^{cm} in length, slender, but very dense-flowered except towards the base, subtended by sheathless bracts with very short blades, the lowest barely half as long as the inflorescence; scale of staminate flower elliptical oblong, pale reddish-brown with green midvein; scale of pistillate flower elliptical, a little darker, spreading and somewhat shorter than the perigynium; perigynium sessile, elliptical, granular, compressed, prominently two-nerved (the lateral), pale greenish brown, the beak short, emarginate: stigmata two.

South Dakota; Rosebud Creek, collected by Mr. E. J. Wallace.

In general habit much like *C. angustata*, but we prefer, nevertheless, to place it near *C. lenticularis*.

Carex dives sp. n. (figs. 8–9).

Rhizome wanting, apparently cæspitose, lower leaf-sheaths light-brown, not fibrillose; leaves as long as the culm, quite broad and flat, scabrous along the margins; culms up till 60^{cm} in height, erect, stiff, triangular, very scabrous, phyllopodic; spikes from six to seven, the terminal and uppermost one or two lateral staminate, the others pistillate, more or less remote and peduncled, especially the lowest one, nodding, very dense-flowered, from 4 to 10^{cm} in length, subtended by sheathless, foliaceous bracts of which the lower ones reach high above the inflorescence; scale of staminate flower linear-oblong, mucronate, pale brown with green midvein; scale of pistillate flower (fig. 8) lanceolate oblong, acute, purplish with green midvein, much narrower, but about as long as the perigynium; perigynium (fig. 9) minutely stipitate to sessile, erect, roundish, compressed, granular, two-nerved, sparingly denticulate along the upper margins, pale green with scattered purplish spots and streaks, the beak very short, entire; stigmata two.

Collected in Oregon by Mr. L. F. Henderson; in California: "in open swamps with *C. utriculata*, 12 mile house San Jose R. R." collected by H. N. Bolander, and in Chilliwack Valley, British Columbia, by Mr. James M. Macoun.

The affinity is with *C. Sitchensis* Prescott.

Carex salina Wahl.

The statement that "this species does not occur on the western side of this continent"* is a mistake, since it has been

* Memoirs Torrey Bot. Club, i, 45, 1889.

collected at several stations on the Alaskan coast, sometimes associated with its near ally, *C. subspathacea* Wormskj.

Carex hæmatolepis Drej.

Described by Drejer* as follows: "Spica mascula 1, femin. 3–5 elongatis cylindraceis laxifloris in pedunculo lævi valido erectiusculis v. demum nutantibus, squamis ovatis acutis serrulato-mucronulatis perigynia ovali-ovata substipitata subsuperantibus, stigmatibus 2–3". "Squamæ ♀ atro-sanguineæ tenuissime punctulatæ nervo tenuissimo discolore, ovatæ, acutæ serrulato-aristatæ v. muticæ, perigynia fere tegentes et superantes. Perigynia obsolete nervata decolora stramineo-viridia, rostro brevissimo integro." Only known from Greenland, but may be found on the northeastern coasts of this continent. It shows some resemblance to *C. cryptocarpa*, but differs from this by the nearly erect pistillate spikes, the mucronate scales and the much narrower perigynia.

Carex cryptocarpa C. A. Mey.

To American botanists this species is so well known and well understood that it should hardly be necessary to make any further mention of it as a little known species. However in a recently published paper dealing with Arctic *Carices*,† the species is enumerated as identical with *C. Lyngbyei* Hornem., with *C. filipendula* Drej. and with *C. capillipes* Drej. and has received the new name *C. Lyngbyei* Hornem., this being older than the name of Meyer. If now the diagnosis of these four formerly recognized species had been drawn up so as to demonstrate their identity, we should have no objection to make, but it seems to us that a comparison of the plants themselves and the original diagnoses makes it rather unnatural to combine them as only one, a fact that becomes more evident when we examine the renewed description of *C. Lyngbyei* (l. c.).

Habitually these four species are somewhat like each other, but *C. cryptocarpa* is readily distinguished by being very robust with broad leaves and heavy spikes, while the others, especially *C. Lyngbyei*, is exceedingly slender in all its parts. The specific characters are, however, to be drawn from the structure of the scales of the pistillate spike and of the perigynium, and we have noticed the following distinctions: The scale is in *C. cryptocarpa:* oblong to oblong-lanceolate, acute with a broad midvein; in *C. Lyngbyei:* lanceolate with the midvein extended into a very long, serrulate awn; in *C. fili-*

* Revisio critica Caricum borealium (Naturhist. Tidsskr. Kjöbenhavn 1841).
† Ostenfeld, C. H., Flora Arctica, Copenhagen, 1902, p. 75.

pendula: ovate, acute to aristulate; in *C. capillipes:* ovate-lanceolate, mucronate. The perigynium is in *C. cryptocarpa:* broadly elliptical, minutely scabrous along the upper margins, and with the veins hardly visible; in *C. Lyngbyei:* obovate, glabrous, prominently veined; in *C. filipendula:* oval to obovate, glabrous, obsoletely veined; in *C. capillipes:* subovate, scabrous along the upper margins, obsoletely veined. In Flora Arctica the description of these four species "*C. Lyngbyei*" reads thus: "scales three-nerved, acuminate with elongated midvein longer than the faintly nerved utricles." In the hundreds of specimens which we have examined of the Alaskan *C. cryptocarpa*, we have invariably found the scales simply acute, and we failed to observe any deviation from the description of the perigynium. In regard to *C. filipendula*, of which we have examined material from Greenland and Iceland, we cannot but express our doubt as to the identity of this with *C. cryptocarpa*, and we are indeed much more inclined to consider it as a nearer ally of *C. salina*, an opinion that has already been pronounced by such critical students of the genus as Blytt and Boott. *C. Lyngbyei* is too characteristic a species to be confounded with any of the others and appears, thus, to be the only endemic species of the Færœ islands; and finally in regard to *C. capillipes* this is yet imperfectly known, but as long as some distinctive characters have been noted, especially in the perigynium, it would be safer to keep it as a distinct species until it is again studied and better known.*

Carex macrochæta C. A. Mey.

Although being exceedingly frequent on the Alaskan coast and the islands, the species shows but slight variation. The terminal spike is usually wholly staminate, but we found, however, a few specimens from Unalaska in which this was either androgynous or gynæcandrous or even entirely pistillate. Two quite striking varieties were noticed, viz:

var. *emarginata* nob.

Taller and more slender than the typical plant; spikes very long, loose-flowered, remote; scales of pistillate spike prominently emarginate with a seta four times as long as the body of the scale.

Alaska: Kukak Bay, collected by Messrs. Coville and Kearney.

*To give the reader some further idea of the treatment of the *Carices* in Flora Arctica, we might quote, for instance, the synonymy given of *Carex rotundata:* "*ambusta*," "*compacta*," "*membranacea*" and "*vesicaria* γ *alpigena*." Such errors are the inevitable result of compilation without access to authentic material and to the most important literature, the works of Boott for instance. It is, indeed, a pity to see the interesting Arctic plants submitted to so poor a treatment.

var. *macrochlæna* nob.

Very robust with four short and heavy pistillate spikes; perigynium very large and longer than the simply mucronate scale.

St. Paul Island, Bering Sea, collected by Mr. James M. Macoun.

Carex nesophila sp. n.

Rhizome stoloniferous with light brown, fibrillose, scale-like leaves; leaves shorter than the culm, relatively broad and flat, glabrous; culm very variable in height from 12 to 38^{cm}, erect, slightly bent near the apex, glabrous, phyllopodic; spikes from two to four,* the terminal staminate, the lateral pistillate or very seldom androgynous, contiguous, sessile and erect or the lowermost borne on exserted peduncles and, sometimes, nodding, all subtended by sheathless bracts with blades about as long as the inflorescence or shorter; scale of staminate flower elliptical, acute, deep purplish with three green midveins; scale of pistillate flower broadly elliptical, acute, purplish to almost black with faintly visible midrib of three veins; perigynium a little longer, but narrower than the scale, sessile, erect, from oval to elliptical oblong, few-nerved, pale green, the beak purplish, very short, entire or obliquely cut; stigmata three or, sometimes, two, the style not exserted.

St. Paul Island, Bering Sea: abundant on uplands with *Sieversia Rossii*, *Artemisia globularis* and *Potentilla villosa*, but not associated with any species of *Carex*, collected by Mr. James M. Macoun (Nos. 16,614 and 16); also on Popoff Island, Shumagin Islands, by Mr. T. Kincaid.

Carex nesophila resembles sometimes certain forms of *C. salina*, but the structure of the perigynium is always more like that of *C. macrochæta*, besides the spikes being contiguous. Although being a rather inconspicuous plant it has been collected in great numbers and only on the islands in Bering Sea, hence the name "*nesophila*."

Carex Schottii Dew. (figs. 10–11).

The species was originally founded on immature specimens from Santa Barbara, California, some of which are in the herbarium at Kew; Mr. Clarke has examined these and informed us that Bolander's specimens No. 1570, collected in swamps at Oakland and in salt-marshes near Fort Point, San Francisco, are identical with these; also identical with Bolander's plant

* As to the number of spikes we find in twenty-two specimens:

15	specimens	with	3	lateral spikes.
5	"	"	1	"
2	"	"	2	"

is the so-called *C. obnupta* Bail., of which Mr. J. W. Congdon has sent us very fine material collected in swamps, Mendocino County, and they all answer the diagnosis of *C. Schottii* very well, but seem distinct from the little that we know of Dewey's *C. Barbaræ.* (Fig. 10 = scale of pistillate spike; fig. 11 = perigynium, both of *C. Schottii.*)

Carex magnifica Dew.

Through the kindness of Mr. Clarke we have learned that most of the specimens of so-called *C. Sitchensis* belong to this unpublished species of Dewey, who sent it to Boott. The real *C. Sitchensis* is a very different plant with slender and remote pistillate spikes, of which we have studied authentic material in the herbarium of Bischoff, which is now in the possession of the St. Louis botanical garden. This species, *C. Sitchensis* Prescott, is known from the coasts of Alaska and Oregon, and has been described as *C. Howellii* Bail.

Mr. Clarke, furthermore, states that Boott's plate 594 (*C. laciniata*), as to the plant depicted, represents *C. Sitchensis* Presc. *vera*, while the details are taken from the old, true *C. laciniata.* Identical with *C. Sitchensis* Presc. are, also, *C. cryptocarpa* Franch. and *C. atrata* Hook et Arn.

Carex lacunarum sp. n. (figs. 12–13).

Roots thick, very hairy; rhizome cæspitose with persisting, reddish brown leaf-sheaths; leaves as long as the culm, relatively narrow, carinate, glaucous and very scabrous; culm about 60^{cm} in height, coarse, triangular, scabrous, phyllopodic; spikes three to five,* the terminal and uppermost lateral staminate, the others pistillate or androgynous, more or less contiguous, sessile or the lower ones peduncled, nodding, cylindric, very dense-flowered, from 2 to 8^{cm} in length, subtended by bracts with blades longer than the inflorescence (fig. 12), sheathless or the lowest one with a short sheath; scale of staminate flower lanceolate, erosely denticulate above, three-nerved, pale purplish with hyaline margins and base: scale of pistillate flower (fig. 13) broadly ovate, acuminate, mucronate to aristate, erosely denticulate above, three-nerved, purplish brown with hyaline margins; perigynium (fig. 13) longer than the body of the scale, sessile or nearly so, erect, rhombic-oval, biconvex, coriaceous, two-nerved, slightly denticulate along the upper margins, otherwise glabrous, pale brown, the beak short, entire; stigmata two.

* As to the number of spikes, staminate and pistillate, we notice in:

7	specimens	2	staminate	spikes.
2	"	1	"	"
4	"	3	pistillate	"
5	"	2	"	"

California: Lagoon at Sebastopol, Sonoma County, collected by Mr. A. A. Heller (No. 5797), and in a marsh at Berkeley, collected by Mr. J. Burtt Davy. The species is nearest related to *C. magnifica* Dew., but is readily distinguished by the lighter color of the spikes and the very dense and regular arrangement of the pistillate flowers.

Carex siderosticta Hance.

We have placed this as a member of the *Lejochlænæ*, and it is interesting to see that in addition to the shape of the perigynium, the species agrees, also, by its monopodial rhizome and long-sheathed bracts, with the central forms: *C. laxiflora*, *Careyana*, etc. Otherwise the lateral spikes are all androgynous, a character which we do not think is sufficient for the segregation of the species from the *Carices genuinæ*.

It is somewhat remarkable that the rhizome is rather slender, creeping and stoloniferous, while most of the monopodial *Carices* have a short, cæspitose rhizome.

Carex cryptostachys Brongt.

As already stated by Boott, this must be referred to the *Dactylostachyæ*, and it possesses the same monopodial rhizome as is observable in *C. digitata* for instance; the structure of the perigynium is much the same, but the ramified culms with quite numerous, androgynous spikes, makes the species appear as the most evolute type of the section.

Carex physochlæna sp. n.

Rhizome loosely cæspitose with persisting purplish leaf-sheaths; leaves much shorter than the culm, very narrow, but flat, scabrous; culms from 30 to 42^{cm} in height, erect, slender, but stiff, trigonous, scabrous, only leafy at the base, phyllopodic; spikes two to three, the terminal staminate, the lateral pistillate, mostly contiguous, sessile, erect, very thick and dense-flowered, subtended by short, filiform, sheathless bracts, the lowest one spreading and about as long as the spike; scale of staminate flower obovate-oblong, obtuse, purplish with green midvein and pale margins; scale of pistillate flower ovate, obtuse, deep purplish to almost black with the midvein obsolete, shorter than the perigynium; perigynium sessile, spreading, oval to oblong, inflated, glabrous, faintly nerved, purplish above, yellowish below, the beak short, bidentate; stigmata three, the style flexuose within the perigynium.

Collected on Coal Creek hill, near the Yukon River, by Mr. Fr. Funston (No. 139).

Very distinct by the heavy, dark spikes contrasting the slender culm and narrow leaves: its nearest ally is *C. physocarpa*.

Brookland, D. C., October, 1903.

Art. XXVIII.—*Characters of Pteranodon (Second Paper)*; by G. F. Eaton. (With Plates XIX and XX.)

Brief notices of some of the characters of *Pteranodon* Marsh were published in this Journal in July, 1903. A restoration of *Pteranodon longiceps* is now about to be installed at St. Louis, which has been prepared under my direction as the contribution of the Department of Vertebrate Paleontology of the Yale Museum to the University's exhibit at the Louisiana Purchase Exposition. It is therefore advisable to describe such additional characters of *Pteranodon* as are manifest in the restoration.

A half-tone engraving of this restoration appears as Plate XIX.

The Sclerotic Circle.

The sclerotic circle is composed of twelve thin plates of bone arranged with overlapping edges, so as to form a hollow truncate cone similar in shape to the avian sclerotic circle. Plate XX, figure 1, shows the arrangement of these plates in the left orbit of a large head of *Pteranodon*. By removing the matrix from under the left side of the skull, which was crushed laterally, the circle was exposed pressed inward against the interorbital septum and with the component plates little disturbed from their normal position.

Professor Williston* refers to the sclerotic circle of the allied genus *Nyctosaurus (Nyctodactylus)* in these words: "It had a ring of thin, large sclerotic plates, which were preserved in displaced positions. The separate plates were not united by imbrication, as in the mosasaurs." The chapter on the Pterosauria in the new edition of Zittel's Paleontology, 1902, as revised by Professor Williston, contains no description of this structure in either *Pteranodon* or *Nyctosaurus*. Oddly enough, in this revision, it is *Pteranodon* that is credited with a sclerotic circle, and not *Nyctosaurus* in which Professor Williston observed the structure.

The Vertebræ.

The most important note to be made here concerns the vertebral formula, which I have now determined. I have figured and described in this Journal (July, 1903) the series of vertebræ which are anchylosed together to support the ilia. Further investigation has shown the number of presacrals attributed to *Pteranodon* by previous writers to be incorrect. Instead of eight cervicals, as given by Professor Williston, there are in reality nine. In the dorsal series are included

* Journal of Geology, vol. x, p. 528, 1902.

eight vertebræ anchylosed to form the notarium, and four free dorsals intervening between the notarium and the sacrum.

Professor Williston has been at considerable pains to demonstrate the number of cervical vertebræ in *Pteranodon* and *Nyctosaurus*, and it is from him I quote:* "If, however, we consider that vertebra which bears the first rib articulating with the sternum to be the first dorsal, then I believe that the prevailing number of cervicals in pterodactyls is eight.

. . . .

"From the foregoing, then, it seems assured that there is a free, short vertebra in front of the notarium, in both *Pteranodon* and *Nyctosaurus*, bearing a free, small rib, which does not unite with the sternum. This vertebra is the eighth cervical, and is probably present in all pterodactyls."

Following the atlas and axis are five vertebræ with long centra, then two vertebræ with short centra, making nine cervicals in all. Plate XX, figures 2, 3, and 4, show the seventh, eighth, and ninth vertebræ in their correct sequence, the longest of the three being the seventh. As there is no doubt that the seventh is the most posterior of the long-bodied cervicals, it is here only necessary to illustrate and call attention to the last three cervicals, and to state that they were preserved in their normal arrangement and that the ninth was in contact with the first true dorsal or notarial vertebra, i. e., the first vertebra connected by ribs with the sternum. I hope to show later that Professor Williston is right in supposing that *Pteranodon* and *Nyctosaurus* have the same cervical formula. The number of cervicals in *Pteranodon*, however, is nine, and not eight as formerly supposed. Fortunately, the material in the Yale University Museum satisfactorily decides this mooted question.

In describing the specimen of *Nyctosaurus* upon which Professor Williston bases his calculation of cervical vertebræ (Osteology of Nyctosaurus), he says that the eighth cervical lay "close to the first notarial vertebra, and near the presternal process of the sacrum," from which statement I must suppose his evidence less satisfactory than my own.

The four free dorsals which follow the notarium are shown in their normal sequence in figures 5, 6, 7, and 8, of Plate XX. Unlike the eight notarial vertebræ, these four were probably capable of slight motion. This is indicated by the character of the articular facets of the zygapophyses and of the ends of the centra. The figures correctly show transverse processes terminating in facets for the support of single-headed ribs. Like all the vertebræ in the entire vertebral column, so far as observed, these four free dorsals are procœlous.

* On the Osteology of Nyctosaurus, Field Columbian Museum, Publication 78, pp. 127, 129, June 1, 1903.

By assuming that the first four vertebræ of the sacral series (in the broader sense) are homologues of the lumbars of other groups, the total number of presacral vertebræ would appear to be twenty-five. This compares closely with the supposed number of presacrals in the Eusuchia.

Paleontological Laboratory,
Yale University Museum, February 29, 1904.

EXPLANATION OF PLATES.

Plate XIX.

Figure 1.—Restoration of *Pteranodon longiceps* Marsh; prepared from the original fossil bones, by H. Gibb, under the direction of G. F. Eaton, at the Yale University Museum, March, 1904. One twenty-fourth natural size.

Plate XX.

Figure 1.—Left orbit and sclerotic circle of *Pteranodon*. The arrow points to the anterior extremity of the head.
Figure 2.—Seventh cervical vertebra of *Pteranodon*.
Figure 3.—Eighth cervical vertebra of *Pteranodon*.
Figure 4.—Ninth cervical vertebra of *Pteranodon*.
Figure 5.—Ninth dorsal vertebra of *Pteranodon*.
Figure 6.—Tenth dorsal vertebra of *Pteranodon*.
Figure 7.—Eleventh dorsal vertebra of *Pteranodon*.
Figure 8.—Twelfth dorsal vertebra of *Pteranodon*.

All the figures are three-fourths natural size, and illustrate the left side of the specimens.

ART. XXIX. — *Palæontological Evidence for the Original Tritubercular Theory;* by HENRY F. OSBORN. (With Plate XXI.)

THERE has been a strong reaction of late against the original tritubercular theory so far as it concerns the origin of the upper molar teeth of mammals, by embryologists, comparative anatomists and palæontologists. Among the latter, Dr. J. L. Wortman has reached especially strong conclusions, which have been published in this Journal.*

According to the original theory of Cope as developed by Osborn, the homologue of the main reptilian cone or protocone is invariably situated on the antero-internal, or lingual side in the upper teeth.

According to the views of the earlier opponents of the tritubercular theory, the protocone is found on the antero-external side, as in the premolars, and corresponds with the cusps which Osborn called the paracone. According to the views of M. F. Woodward,† which were based on embryology, the protocone varies in position in different groups of mammals, namely, antero-internal in certain zalambdodont insectivores (Centetes), and antero-external in Dilambdodonta (Erinaceus), as well as in most other mammals. Similarly Wortman, by analogy with the premolars (this Journal, November, 1903), believes that the position of the protocone may have been variable, that is, in some cases internal, in others external.

The whole point of this very complex question turns on the simple question of evidence whether the main reptilian cone, or *protocone*, of the ancestors of mammals was found upon the antero-internal side or on the antero-external side of the upper molars.

The original evidence upon which Osborn supported and developed Cope's theory is that derived from the rare upper molar teeth of the Jurassic mammals. Osborn‡ cited (1) the upper teeth of *Triconodon*, in which the main cone is *central*, (2) the upper teeth of *Peralestes* (British Museum) fig. 2, in which the main cone is *internal*, (3) the upper teeth of *Kur-*

* "In view of the facts above set forth, however, I am more firmly than ever of the opinion, that all such attempts [to name the cusps of the molars in accordance with their supposed homologies, rather than with their relative positions] are foredoomed to failure, and I believe they should be abandoned as utterly useless and confusing; that of Professor Osborn, being doubly erroneous, is therefore the most open to objection in this regard." (This Journal, vol. xvi, November, 1903, p. 368.)

† Proc. Zool. Soc., Lond., 1896, pp. 557–594.

‡ On the Structure and Classification of the Mesozoic Mammalia. Jour. Acad. Nat. Sci., Phila. (2), ix, pp. 242–246.

todon, fig. 3, in the British Museum in which the main cone is *internal*, (4) a reference by Professor Marsh to the fact that in the upper molars of *Dryolestes* the main cone is *internal*. In each case the main cone was believed to be the protocone.

The teeth last mentioned (4) were not personally examined at the time, but through the kindness of the late Professor Charles E. Beecher I was recently enabled to study them in the Yale University Museum.

The specimens consist of two superior series. They both show that the large, single, main cusp of the crown is *internal*, and in my opinion they present *conclusive evidence of the truth of the tritubercular theory as originally proposed.*

More in detail, the two specimens taken together show perfectly the structure of both the crowns and fangs of seven superior molar teeth, and confirm entirely the general description given by Marsh, to which some important points may be added as follows:

(1) The molars are sharply distinguished from the premolars, which are bifanged teeth with simple, laterally compressed crowns. (2) The molar crowns are broadly transverse or triangular, and upon the *internal* side of each is a large, conical, pointed cusp, *pr*, supported by a large, stout fang, fig. 1 A, *m6*, *m7;* around the inner side of each of these cusps is a delicate cingulum, fig. 1 A, *c*. (3) The *external* portion of the broadly triangular crown is supported on two smaller fangs, fig. 1 A, *m6*, *m7*. (4) The external portion of the crown is depressed, and bears one large antero-external cusp *?pa* and one smaller postero-external cusp *?me* which is either partly worn away or less pronounced in development. (5) Outside of this external wall there is also a faint basal cingulum, *c*, *c*, *c*. (6) Connecting these low external cusps with the elevated internal cusp are two transverse ridges; the anterior transverse ridge is higher and stronger than the posterior.

These features are clearly shown in the accompanying drawings, fig. 1, which were made and shaded under the camera lucida and therefore admit of no doubt as to interpretation.

These two specimens fully supplement and confirm each other; they also supplement the evidence derived from the study of the superior molar teeth of *Peralestes* (fig. 2) and of *Kurtodon* (fig. 3) in the British Museum, which were cited and figured in my memoir and in various subsequent papers on trituberculy.

Again summing up this combined evidence, we find in the Jurassic period the superior molars of the only mammals known (excepting the Triconodonta and Multituberculata) to consist of a large conical internal cusp or *protocone*, which we

have every reason to believe is homologous with the large external cusp or *protoconid* in the lower jaw.

Secondly, that the external cusps in the superior molars are depressed and comparatively small, consisting of two, more or less well-defined cusps. Thirdly, that this palæontological evidence lends no support, either in crown or fang structure, to the evidence of embryology that the paracone (*?pa*, or antero-external cusp) is the oldest cusp. Fourthly, that it lends no support to the premolar-analogy theory, which was originally suggested by Huxley* in his description of the teeth of the Canidæ in 1880, which has been supported by Scott and other palæontologists, and finally set forth with fresh arguments by Dr. Wortman; this 'premolar-analogy' theory is to the effect that the key to the past evolution of the molar teeth is to be found in the subsequent or present evolution of the premolar teeth, and that thus in many groups of animals at least the protocone occupies the same position in the upper molars as in the upper premolars. Fifthly, that all the known Upper Cretaceous mammals with triangular molars accord with the Upper Jurassic mammals in exhibiting the antero-internal cone as the main cone. Finally, that no such variations of structure are observed in the upper molars of the most primitive mammals as would be the case if there had been different modes of origin of the triangular or tritubercular crown.

In a succeeding article I shall take up and discuss some of the other points and theories raised in Dr. Wortman's interesting and important papers.

EXPLANATION OF PLATE XXI.

FIGURE 1.—Superior molars of *Dryolestes* Marsh. *A*. Series of the left side, external and crown views. *B*. Series of the right side, external, crown and internal views. Yale Museum.
pr, *pr*, *pr*, main internal cusps believed to be protocones.
?pa, *?me*, smaller external cusps believed to be para- and metacones.
c, *c*, *c*, external and internal cingula.
i. o. f. infraorbital foramen.

FIGURE 2.—Superior molars of *Peralestes* Owen. Right side. External, oblique and crown views. British Museum.
mts, metastyle. Other abbreviations as in fig. 1.

FIGURE 3.—Superior molars of *Kurtodon* Osborn. Left side. British Museum.

* Collected Memoirs, vol. iv, p. 450.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Gases Occluded or Evolved by Radium Bromide.*—Dewar and Curie describe some experiments made with 0·4^{g} of radium bromide. The pure, dry salt was placed in a glass tube communicating with a small Geissler tube and a mercury manometer, and a very perfect vacuum was produced in the apparatus. During three months gas was given off at the rate of 1^{cc} per month, and an examination of the spectrum by means of the Geissler tube showed only the presence of hydrogen and the vapor of mercury. It is possible that a minute quantity of moisture was introduced with the salt, and that this was gradually decomposed under the influence of radium.

The sample of radium bromide was then taken to England in order to make other experiments with it, and there it was transferred to a vessel of fused quartz, where it was heated to fusion at a red heat after the air had been exhausted by means of a mercury pump. The gases given off in this operation were passed through three U-tubes cooled with liquid air, which retained the greater part of the radium emanation and the less volatile gases. The more volatile gases collected in this way amounted to 2·6^{cc}; they had carried with them some of the emanation and were radio-active and luminous. Dewar examined the spectrum of this spontaneous light by means of a photographic spectroscope with a quartz prism and an exposure of three days, with the result that three bands belonging to nitrogen were obtained. When the gas was subjected to the electric discharge in a Geissler tube, the spectroscopic bands of nitrogen were also obtained, and upon condensing the nitrogen by exposure to the temperature of liquid hydrogen a high vacuum was produced in the Geissler tube, and the spark then indicated the presence of nitrogen, but nothing else.

The quartz tube containing the radium bromide which had been fused and thus freed from occluded gases was then sealed while exhausted, by means of the oxyhydrogen blowpipe, and taken back to Paris. Then, twenty days after it had been sealed, Deslandres illuminated the interior of the tube by a Ruhmkorff coil by the aid of small coatings of tin-foil applied to the exterior of the ends of the tube, and obtained the complete spectrum of helium, with no other lines, by means of a photographic spectroscope with a quartz prism. This result agrees with those of Ramsay upon the production of helium by radium salts dissolved in water, and it is interesting in showing that the presence of water is apparently unnecessary for this production of helium.—*Comptes Rendus*, cxxxviii, 910. H. L. W.

2. *Uranyl Double Salts.*—Rimbach, Bürger and Grewe have prepared a large number of these double salts, many of which

are new, and have studied their solubility in and decomposition by water. It was found that a large number of double chlorides, bromides, and sulphates correspond to the type $UO_2X_2'\cdot 2XX'$, while the double nitrates, chromates, and fatty-acid salts belong to the type $UO_2X_2'\cdot XX'$, where X signifies an atom of a univalent metal, and X' a valency of a negative atom or radical. There are also exceptional types, such as $UO_2X_2'\cdot 4XX'$.

The stability of the double salts with water was found by analyzing saturated solutions of them prepared at different temperatures. When the ratios of the constituents in solution did not agree with the composition of the original compound, decomposition by water was shown. It was found that all the double nitrates are thus decomposed at the lower temperatures experimented with, while the double chlorides are more stable, and those containing alkali-metals of higher atomic weights (Rb and Cs), or complex radicals of strongly basic character, are not decomposed at the observed temperatures. The alkali-metal double sulphates are also stable, except when they form salts of the type $UO_2X_2'\cdot 4XX'$, which are extensively decomposed by water. All of the salts decomposed by water were found to become stable at higher temperatures, usually at about 60 or 80°. —*Berichte*, xxxvii, 461. H. L. W.

3. *The Presence of Formic Aldehyde in the Atmospheric Air.* —In the course of researches upon the atmospheric air, H. Henriet has detected the existence in it of a gaseous substance, other than formic acid, possessing energetic reducing action, and capable of reducing Fehling's solution and of decolorizing iodide of starch. In order to study this compound and to determine its identity, he examined rain-water which came from fogs. The samples of water, after filtration, were concentrated slowly upon the water bath from a volume of 30 or 40^{l} to about 200^{cc}. The samples were neutral at first, but became acid upon concentration, and deposited a certain quantity of calcium sulphate which was removed by filtration. The products which were strongly colored, with an orange-yellow tint, were subjected to simple distillation, and the distillates contained formic acid and a reducing agent which distilled in the presence of acids or alkalies, and gave the general reactions for aldehydes as well as special reactions for formic aldehyde.

The author concludes that formic aldehyde exists in the air, and that this substance, which is a powerful antiseptic, plays an important rôle in connection with the purity of the air.— *Comptes Rendus*, cxxxviii, 203. H. L. W.

4. *Revision of the Atomic Weight of Iron.* — About four years ago Richards and Baxter, by the reduction of ferric oxide by hydrogen, obtained the value 55·883 (O = 16·000) for the atomic weight under consideration. Baxter has recently made further determinations of this atomic weight by comparison of carefully purified and sublimed ferrous bromide with the silver bromide produced by it, or, in other cases, the silver required to

react with it. The average result, after all corrections had been made, was 55·870, a remarkably close agreement with the result of the other method.

In connection with this work the effect of the earth's magnetism upon the weight of magnetic substances has been discussed, and it has been shown by experiment to be entirely inappreciable.—*Zeitschr. Anorgan. Chem.*, xxxviii, 232. H. L. W.

5. *Method of Separating Iron and Aluminium.*—A method for making this analytical separation by boiling in the presence of an excess of sodium thiosulphate has been suggested by Chancel, but it has not been found satisfactory. LECLÈRE has modified the method by first adding ammonium thiosulphate to the very dilute solution containing a slight excess of sulphuric acid. This reduces the iron to the ferrous condition. Then a large excess of ammonium formate is added, and the aluminium is precipitated by boiling, in the state of basic formate. In drying the precipitate it is advisable to treat it with nitric acid, in order to destroy formic acid and prevent the presence of a residue of carbon in the ignited alumina. The iron can be precipitated in the filtrate as sulphide.—*Comptes Rendus*, cxxxviii, 146. H. L. W.

6. *Phosphorescence.*—ALBERT DAHMS gives an historical summary of the results of Seebeck and of Becquerel; and takes up the study of the phenomena discovered by them with the additional aid of photography. A number of interesting photographs accompany the paper. The various substances were exposed to the light of the carbons of an electric arc, and the photographs show carbon bands in the blue portion of the spectrum, and also in some cases bands in the extreme infra-red. The author shows that the phenomena are conditioned not only by the relative velocities of the rays, but also by the amount of energy contributed to the phosphorescent substances, and also by the inherent energy of such substances.—*Ann. der Physik*, No. 3, 1904, pp. 425–463. J. T.

7. *Preliminary Measurements of the Short Wave Lengths discovered by Schumann.*—For the past few years Dr. Theodore Lyman has been engaged in the Jefferson Physical Laboratory in an attempt to measure the short wave lengths discovered by Dr. Victor Schumann; but it is only recently that this attempt has proved successful.

Working in an atmosphere of hydrogen with a concave grating ruled upon speculum metal, an end-on tube filled with hydrogen gives numerous lines below the aluminum group at 1854. The shortest wave length so far observed has a value 1178 Ångström units. The limit of error is two units.

It is interesting to note that, contrary to expectation, speculum metal is able to reflect these very short wave lengths to a considerable degree. This is merely a preliminary notice. The author has in preparation a complete list of these new wave lengths; and he has good hopes of still further extending the spectrum. It is

his purpose to publish a detailed account of the investigation in the Proceedings of the American Academy and perhaps elsewhere.

J. T.

8. *Heating effect of the Radium Emanation.* — It has been shown that the radiation emitted from a radium compound in a state of radio-active equilibrium may be divided into three parts:

(1) A non separable radiation consisting entirely of α rays; and constituting about 25 per cent of the total radiation.

(2) The radiation from the emanation occluded in the radium, also consisting entirely of α rays.

(3) The excited radiation produced in the mass of the radium, consisting of α, β, and γ rays.

(2) and (3) together constitute about 75 per cent of the total radiation.

It is found that the emanation supplies 18 per cent, the non-separable activity 25 per cent, and the excited activity 57 per cent of the total activity of radium. On heating or dissolving a radium compound in an open vessel, the emanation is released and can be entirely removed by a current of air. The excited activity, or emanation X, is non-volatile, and being left in the radium immediately begins to decay. Since fresh emanation is being constantly produced by the radium and occluded in it, the activity of the radium after falling to a minimum gradually rises again, and in the course of a month nearly reaches its original constant value. Interesting curves are given of the energy of the various forms of activity; and calculations of the amount of heat from the emanation. It is computed that the amount of heat liberated per hour from 1^{cc} of the emanation lies between $1{\cdot}25 \times 10^5$ and $1{\cdot}25 \times 10^6$ gram-calories. This amount of heat would probably be sufficient to raise to a red heat, if not to melt down, the glass tube containing it. One pound weight of the emanation would initially radiate energy at the rate of 10^4 to 10^5 horse-power, and while the heating continued would emit an amount of energy between 6×10^4 and 6×10^5 horse power days. According to the author's disintegration hypothesis, this energy is derived from the energy latent in the radium atoms and is released in the various stages of their disintegration. — *Rutherford and Barnes in Phil. Mag.*, Feb., 1904, pp. 202–219. J. T.

9. *Nature of the Emanations from Radium.*—Lord KELVIN finds it difficult to believe in the atomic disintegration hypothesis of Rutherford, and suggests that radium may transform etheric vibrations into its peculiar manifestations of energy, just as a black cloth in a test tube filled with water shows an increase of heat over a similar receptacle filled with water and containing a piece of white cloth.—*Phil. Mag.*, Feb., 1904, pp. 220–222.

J. T.

II. Geology and Natural History.

1. *United States Geological Survey.* — The following folios have recently been published:

No. 97. Parker folio, South Dakota; by J. E. Todd.

No. 99. Mitchell folio, South Dakota; by J. E. Todd.

No. 100. Alexandria Folio, South Dakota; by J. E. Todd and C. M. Hall.

Four connecting folios dealing with the James River region have thus far been published and they show clearly the unity of this geologic province. Sioux quartzite (Algonkian) underlies the region and constitutes the "bed rock" of the well drillers. The Paleozoic, Triassic and Jurassic are absent, and the Cretaceous is represented by the Colorado Group (Benton and Niobrara). Rock outcrops are exceedingly rare and the distribution and characters of the pre-glacial formations is determined in large measure from the numerous artesian well records.

The whole area is practically a plain of till diversified by a series of moraines left by the retreating glacial lobe. The till is from 10 to 350 ft. deep and appears to belong entirely to the Wisconsin epoch. No complicated drainage modifications are apparent, and, in fact, the area exhibits simple geologic structure in every respect. These three folios together with the Olivet (No. 96), are particularly valuable for their descriptions of glaciation and artesian water conditions.

No. 98. Tishomingo folio, Indian Territory; by Joseph A. Taff. The Tishomingo quadrangle exhibits two types of topography; a Cretaceous peneplain composed of Paleozoic formations, and a dissected plain of Cretaceous strata. In addition to the Cretaceous, Cambrian, Silurian, Devonian, and Carboniferous strata are represented. A pre-Cambrian granite occupies a considerable area and with it are associated a quartz-monzonite and numerous dikes of diabase, diorite and aplite intruded at different times. A commendable feature of the folio is the publication of lists of fossils with each formation and the attention given to correlation. The Arbuckle uplift, occupying the northern half of the quadrangle, is composed of a number of folds, constituting a broad arch. The synclines are faulted to an extraordinary degree, the main faults being approximately parallel with the folds. "The folds are open and never overturned" . . . "and the faulting, in most cases at least, is of the normal type or drop faulting." Asphaltic deposits of economic importance occur in the Ordovician sandstone and limestone, and to less extent in the Carboniferous limestone conglomerate.

2. *Glacial Geology of Tasmania;* by J. Walter Gregory. Quart. Jour. Geol. Soc., lx, 37.—The existence of Carboniferous glacial beds in Tasmania has long been known, and in 1894 E. J. Dunn furnished the first conclusive evidence of Pleistocene glacial action, after an examination of the summits of the Western Highlands. Prof. Gregory now shows that, contrary to the view

held by most observers of that region, there has been widespread glaciation in Tasmania down at least to the 400 ft. level. These low level deposits are best preserved in the valleys of the King, the Linda and the Pieman River.

3. *Report on a Geological Reconnoissance of the Iron Region of Angat, Bulacan;* by H. D. McCaskey. 62 pp., 56 pls. Bull. 3, Mining Bureau Phillippine Islands.—A sketch of the Geology of the Province of Bulacan shows many interesting features. The rocks described are pre-Tertiary crystallines (diorites?), modern volcanics, Tertiary or early Quaternary sedimentary rocks, tuff deposits, alluvium. One fossil found is of early Mesozoic or late Paleozoic age. The photographs, tables of analyses and maps are valuable additions to the text.

4. *Mineral Tables for the Determination of Minerals by their Physical Properties*; by Arthur S. Eakle. Pp. 73. New York, 1904 (John Wiley & Sons).—Mineral tables, based upon physical properties, have the advantage as compared with those which are strictly chemical, that they call the attention of the student to the visible characters of the specimens he is handling, and hence tend to increase his knowledge of them. The Weisbach tables have been long and favorably known, but this volume now issued differs from them, in that the fundamental basis of classification is that of *color*. The arrangement is based, first, on the color of the fine powder, the *streak*, and second upon the color of the mass. The individual species, with their other characters given in tabular form, are arranged by their specific gravities. The tables have evidently been carefully prepared, and under the guidance of a good teacher should give excellent results.

5. *Meteorite Catalogues.* — The catalogue of the Collection of Meteorites of the Field Columbian Museum in Chicago, compiled by Dr. O. C. Farrington, has recently been issued. It shows that the collection has grown from the 179 falls in July 15, 1895, to 251 falls in May 1, 1903, and the total weight from 2,099 to 2,289 kilograms. The collection has large masses of the following: Brenham 445 kgs., Canyon Diablo 690 kgs., Long Island 528 kgs., Toluca 177 kgs.

A catalogue of the collection of the Berlin University, by Prof. C. Klein, has also appeared. This collection is now one of the largest in the world in number of falls, the total number amounting to 450. The latest estimate (quoted by Klein) for the Vienna collection gives 560 localities in 1903, for London 476 in 1896, for Paris 466 in 1898. In addition to the classified list of meteorites, this catalogue also contains more or less detailed descriptions of several meteorites. A point of unusual interest is the identification of the mineral *leucite* which is present in minute trapezohedrons in the Schafstädt meteorite (1861) with anorthite, augite, etc.; it is probably also present in the Pawlowka (1882) meteorite.

6. *The Fauna and Geography of the Maldive and Laccadive Archipelagoes;* edited by J. Stanley Gardiner. Vol. II, Part

II, pp. 589–698, with text figures and 12 pls. (See this Journal, xiii, 321; xiv, 74; xv, 240, 488; xvi, 400.)—Mr. E. A. Smith, in his report on the "Marine Mollusca" of the expedition, mentions that this collection is of special interest, as being the first of any importance ever studied, from this region. Among the 380 species found, probably all of the more conspicuous forms which actually occur there are represented, only the more obscure or smaller ones having been overlooked. Although the fauna is similar to that of the islands of the Indian Ocean, it is curious that the larger proportion of the species have been previously noted from the China Seas eastward and in the Pacific. Many common widely distributed species are represented, although certain genera which occur in the surrounding seas do not appear. About three-quarters of the species are known to exist in the seas surrounding the Philippine Islands and Malay Archipelago and farther north; about one-quarter are similar to those from Japan. Twenty-two species are described as new, most of which are well figured.

Mr. R. A. Punnett reports the collection of "Enteropneusta," in numbers and variety of forms, to be the most extensive ever made. Seven species and one genus (*Willeyia*) are described as new and the genus *Ptychodera* is for the first time thoroughly studied.

Mr. L. A. Borradaile continues his extensive studies of the "Marine Crustaceans;" his report on the "The Spider-crabs (*Oxyrhyncha*)" being his tenth contribution. Of the twenty-nine species recorded, three are described as new. "The Classification and Genealogy of the Reptant Decapods" is also given.

K. J. B.

7. *North American Fauna, No. 23, Index Generum Mammalium:* A list of the genera and Families of Mammals by T. S. Palmer, Assistant Biological Survey. Prepared under the direction of Dr. C. Hart Merriam, Chief of Division of Biological Survey. Pp. 984. Washington, 1904.—Of the three parts of which this comprehensive work consists, part 1 (pp. 7–718), giving an annotated list of the generic names of mammals, was begun in 1884 by Dr. Merriam and completed by Dr. Palmer. Parts 2 and 3 have been prepared by Dr. Palmer alone; they give (2) an alphabetical list of families of mammals (pp. 719–776) and (3) a classified list of the generic names arranged by orders and families (pp. 777–984).

III. Miscellaneous Scientific Intelligence.

1. *Christian Faith in an Age of Science;* by William North Rice. Pp. 425, New York, 1903 (A. C. Armstrong & Son).—The question to which an answer is offered in this most interesting volume is, "Can the faith which first breathed in the unscientific atmosphere of the first century survive in the scientific atmosphere of the twentieth century?"

The great value of the book lies in the fact that the author combines in his own personality the highest training, knowledge and practical comprehension of modern science with a profound and reverent Christian faith.

In the first part a general survey of the progress of human knowledge is presented, precise and exact in its criticism. It is shown how step by step the crude fancies of a timid, ignorant and superstitious people have been replaced by the exact and demonstrated facts and laws of science:—a flat world, with the mountain pillars supporting the roof of heaven, has become a globe whirling free in space; geocentric astronomy, the seven days of creation, miracles, spontaneous generation and a carpenter idea of, and an interfering God, have become the heliocentric solar system, the illimitable spaces of the universe, the millions of years of geologic time, the orderly evolution of worlds, of the structure of the earth and of organisms, the conservation of energy and the unerring sequence of cause and effect. These advances of knowledge have seemed to take away the very foundation upon which the old systems of theology rest.

In the second part, with the same calm, scientific method, the author shows how religious ideas have become clarified and their essential truths brought out more distinctly, as the world has advanced. We find in his terse, but sufficiently full, portrayal of the modern conceptions of the personality of man and of God, the scientific conception of providence, of prayer and the nature and meaning of the bible, an admirable and sufficient answer to his original question.

The conclusion reached is that, although, as in science "certainty in natural science is demonstrated to be absolutely unattainable;" so "no claim of certainty can be maintained in regard to Christianity as a system or in regard to any particular doctrine of Christianity." Nevertheless, it is a fact, that, "The generation in which we live—the generation which has accepted the doctrines of modern science—is more strongly influenced by the teachings of Christianity than any previous generation, and multitudes of men and women find that the acceptance of scientific teachings in no wise disturbs their personal religious life," and "our partial knowledge justifies the prophetic hope that no scientific discovery will contradict the essence of Christianity, and that the end of all questioning will be the reëstablishment of faith." H. S. W.

2. *Beiträge zur chemischen Physiologie;* herausgegeben von F. Hofmeister. IV. Band, 9–12; Braunschweig, 1903 (Vieweg u. Sohn).—The closing parts of this volume contain a number of important papers among the fifteen contributions. These include extensive studies on the occurrence of albumoses in the blood, by O. Schumm; two papers on glycolytic ferments; an elaborate investigation of the antecedents of the fibrin ferment, by Morawitz; and several contributions pertaining to the chemistry of the proteids. The possibility of transforming albumins into globulins is emphasized in detail by L. Moll; and Embden and v. Fürth have demonstrated that the rapid disappearance of typ-

ical effects after suprarenin (adrenalin) injections is not due to any rapid oxidation of this compound in the body, but rather to its gradual dilution by diffusion and distribution in the organism.

L. B. M.

3. *Astronomical Observatory of Harvard College*, Edward C. Pickering, Director.—Recent publications are the following:

Annals, Vol. XLIII, part iii. Observations and Investigations made at the Blue Hill Meteorological Observatory in the years 1901, 1902, under the direction of A. Lawrence Rotch; with appendices containing a discussion of the effect of meteorological conditions upon audibility; also the observations with kites, 1897–1902, and a description of the kites and instruments. Pp. 115–239, with four plates.

Annals, Vol. XLVIII, No. ix, Geographical Position of the Arequipa Station, by Winslow Upton, pp. 221–273.

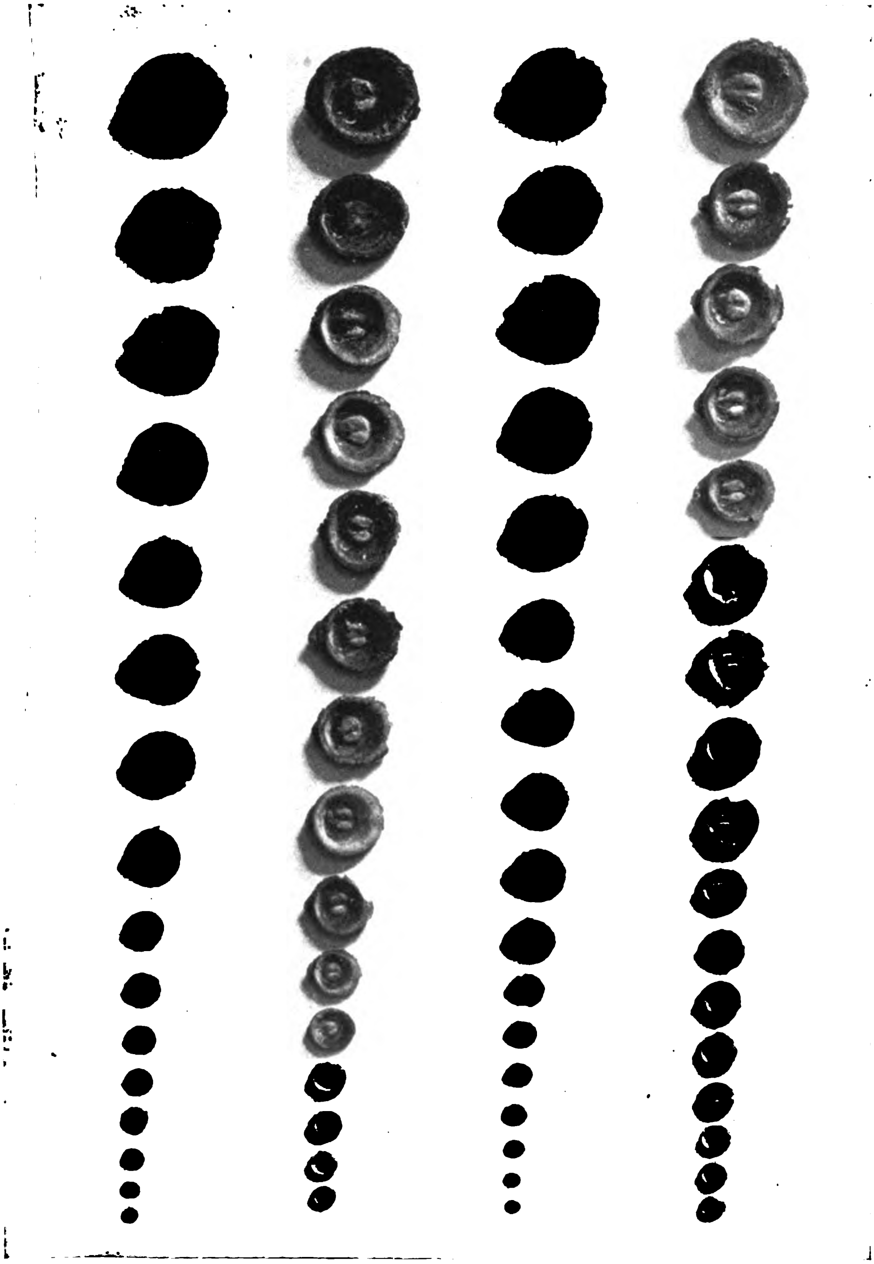
Circular, No. 74. Variable Stars of long Period, pp. 10. No. 75, Variability of Iris (7).

4. *Publications of the United States Naval Observatory*, Rear-Admiral Colby M. Chester, U. S. N., Superintendent. Second Series, Volume V. *Meteorological Observations and Results, 1893–1902.* Pp. x, 443, 4to. Washington, 1903.—This volume contains the usual meteorological observations, given in tabular form, of barometric pressure, temperature, wind direction and velocity, etc., taken at the Naval Observatory, Georgetown Heights, during the decade from 1893 to 1902.

5. *Where did Life Begin?* by G. Hilton Scribner. 75 pp. New York, 1903. (Charles Scribners' Sons.)—In 1883 Mr. Scribner published a monograph advocating the theory that living forms originated within the circumpolar area. This book is now republished, and it is worthy of note that the "Scribnerian theory of the Place of the Origin of Life" is in accord with the conclusions reached by Dr. J. L. Wortman from a study of vertebrate fossils and by Dr. Wieland from a study of fossil plants (this Journal, xv, 419; xvi, 401).

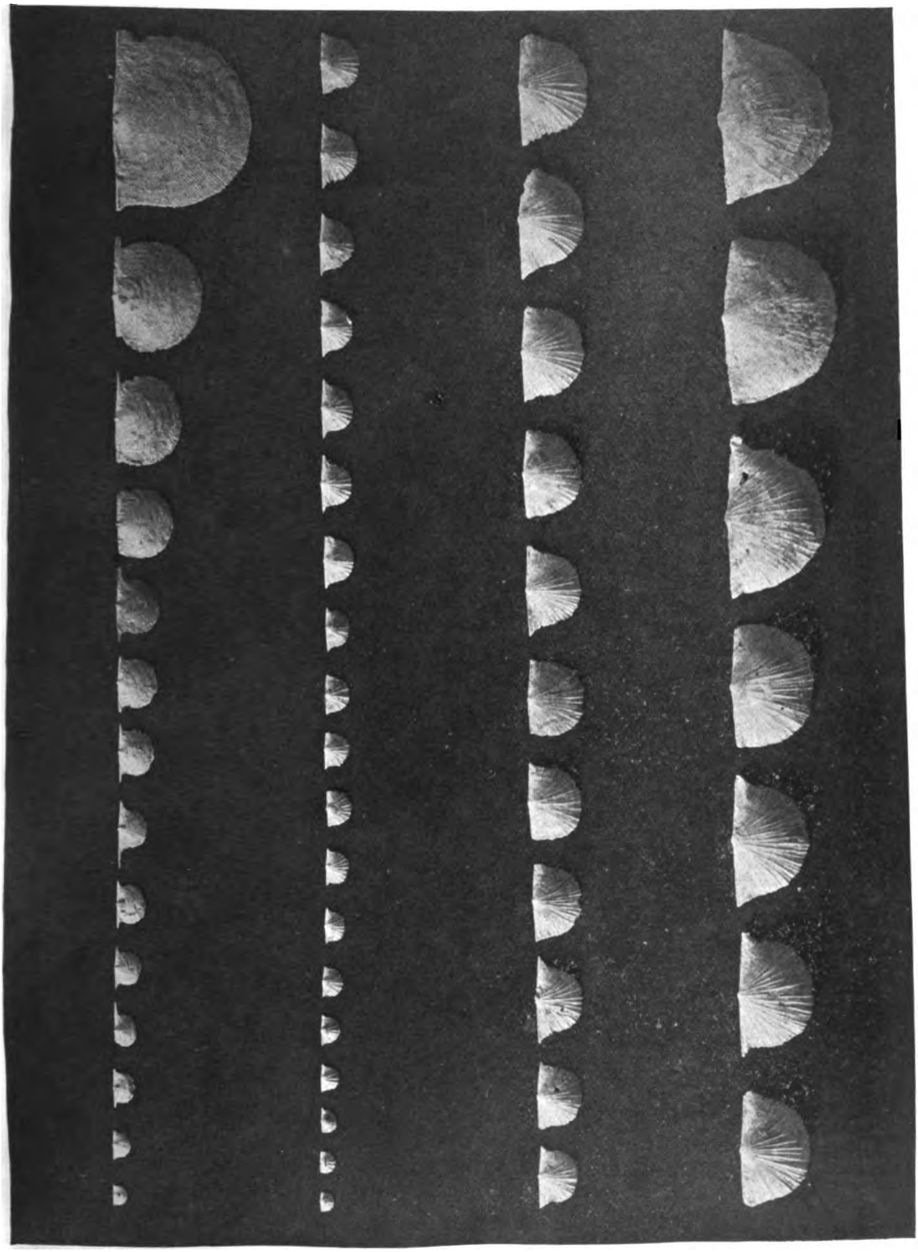
6. *Field Columbian Museum.* — Among the recent publications is to be mentioned Vol. IV of the Anthropological Series by George A. Dorsey (pp. xii, 228, with 139 plates), giving a minute and fully illustrated description of the famous Arapaho Sun Dance. Other publications are the following: On the Osteology of *Nyctosaurus* (Nyctodactylus) with notes on American Pterosaurs by S. W. Williston. Structure and Relationship of Opisthocœlian Dinosaurs, Part 1, *Apatosaurus* Marsh; by E. S. Riggs. Catalogue of Meteorites by O. C. Farrington, mentioned on p. 329.

7. *Bureau of American Ethnology: Twentieth Annual Report to the Secretary of the Smithsonian Institution, 1898–99;* by J. W. Powell, Director. Washington, 1903.—This volume contains the report of the Director (pp. i–ccxxiv) and also an interesting paper by W. H. Holmes (pp. 1–237) giving a description of the aboriginal pottery of the eastern United States, illustrated by a hundred and seventy-seven plates and seventy-nine text figures.



1 2 3 4

PHOLIDOPS OBLATA Hall. ×2.



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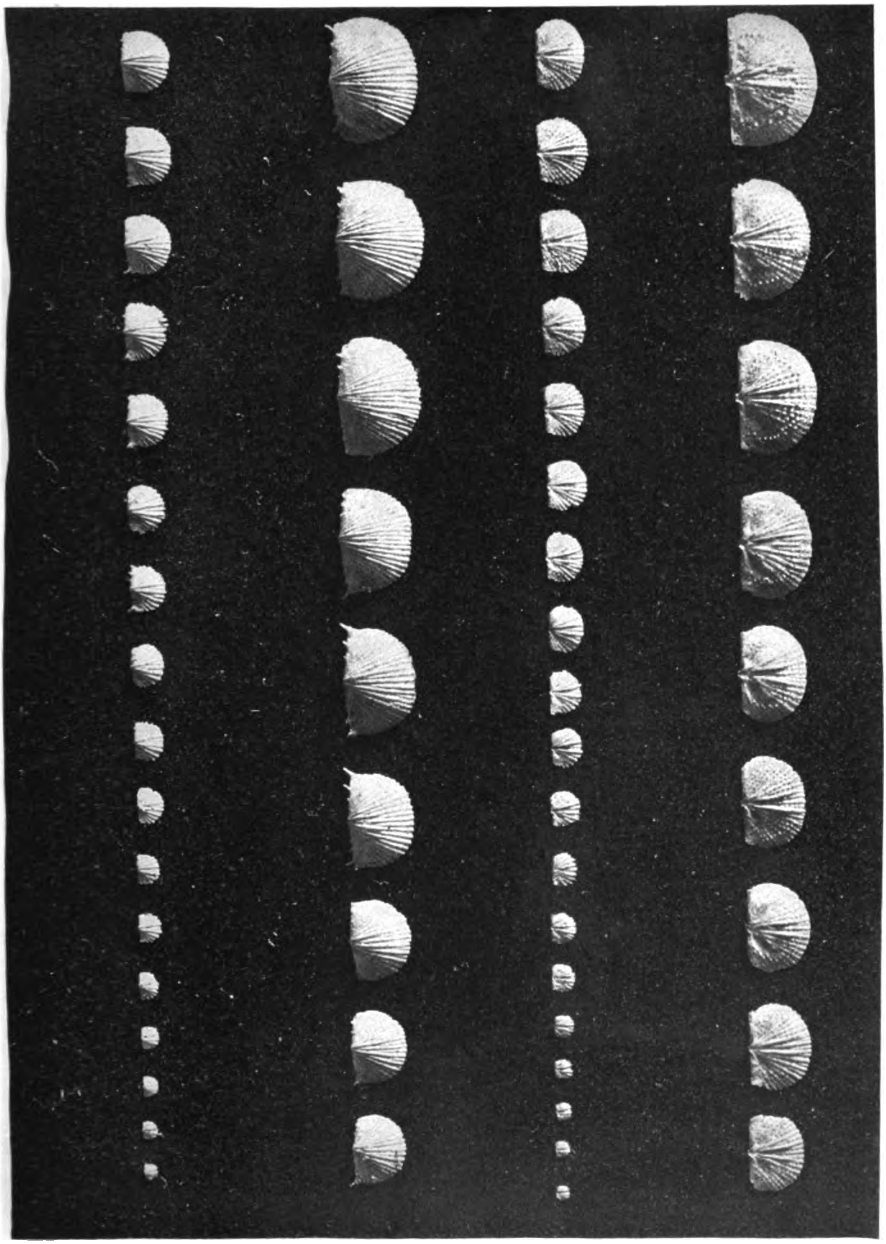
2–4.—Stropheodonta inæquistriata Conrad. ×1.



1 2 3 4

CHONETES SCITULUS Hall. ×2.

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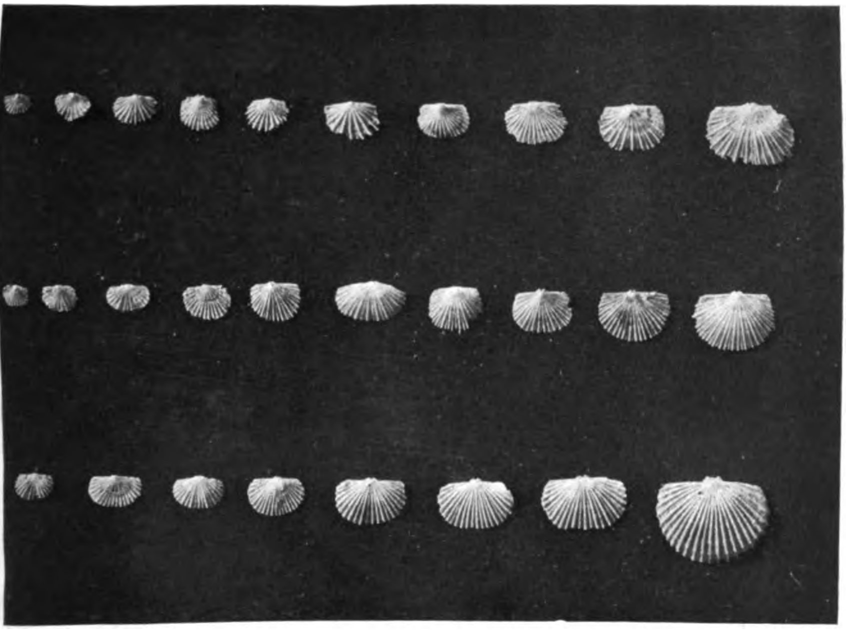

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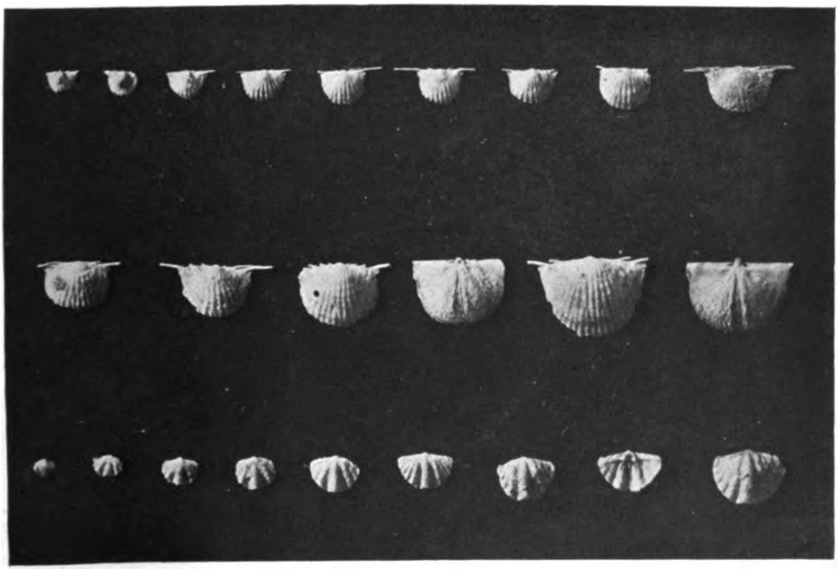
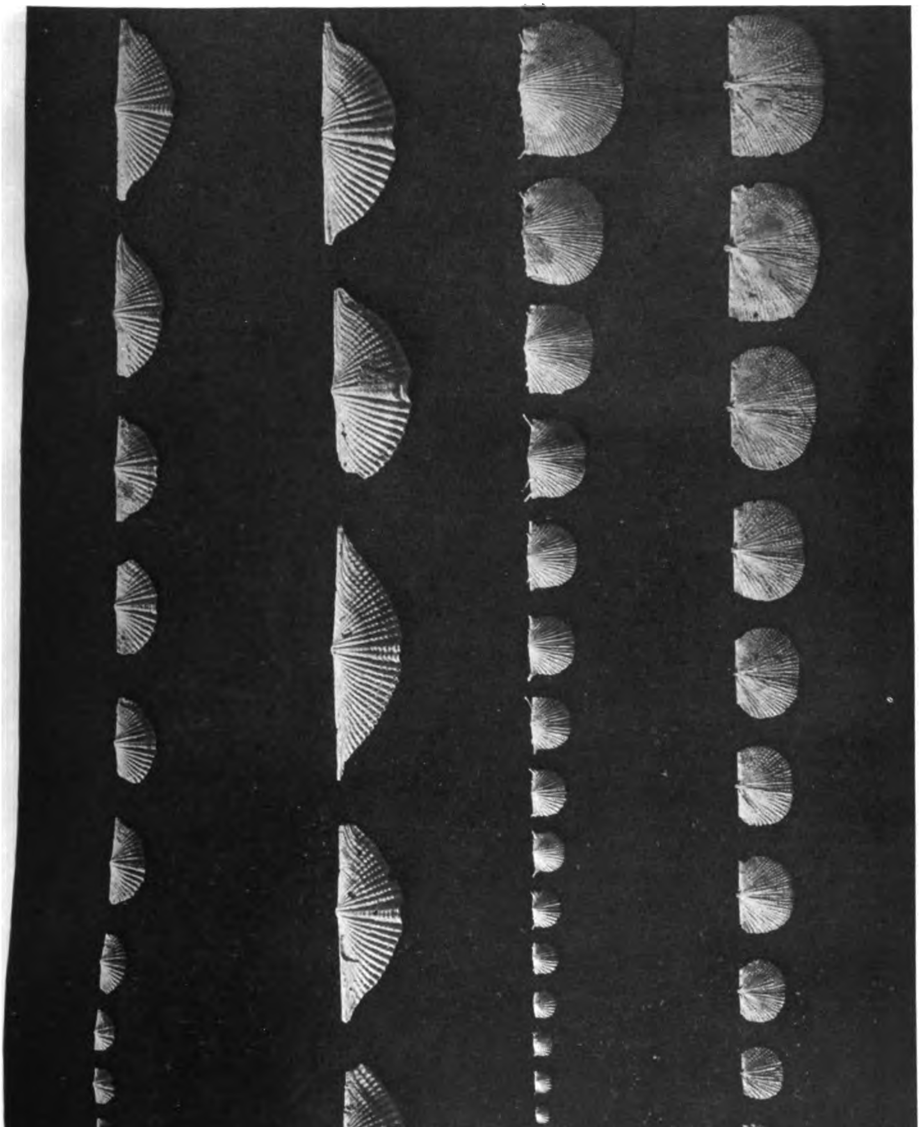
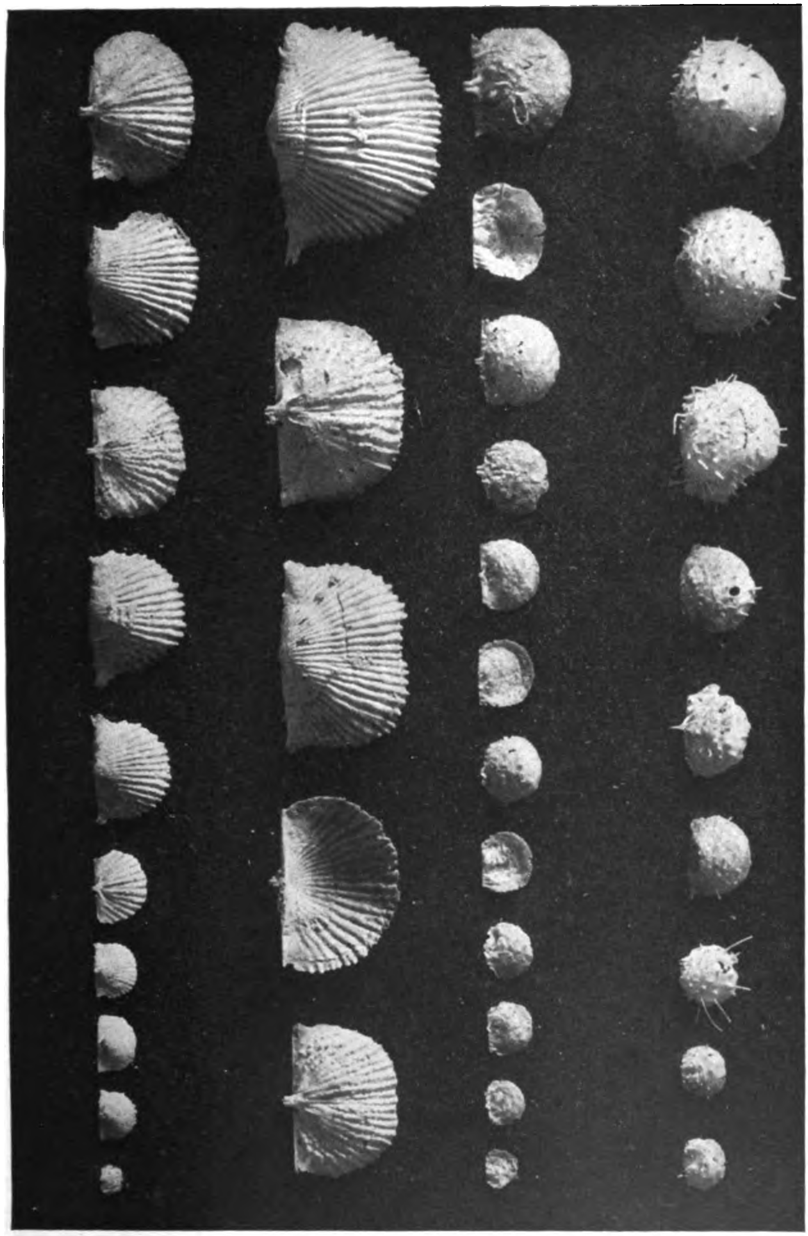


1.—Orthothetes chemungensis var. pectinacea Hall. ×2.
2.—Orthothetes chemungensis var. arctistriatus Hall. ×2.
3.—Orthothetes bellulus Clarke. ×2.
4, 5.—Chonetes mucronatus Hall. ×2.
6.—Cyrtina hamiltonensis Hall. ×2.



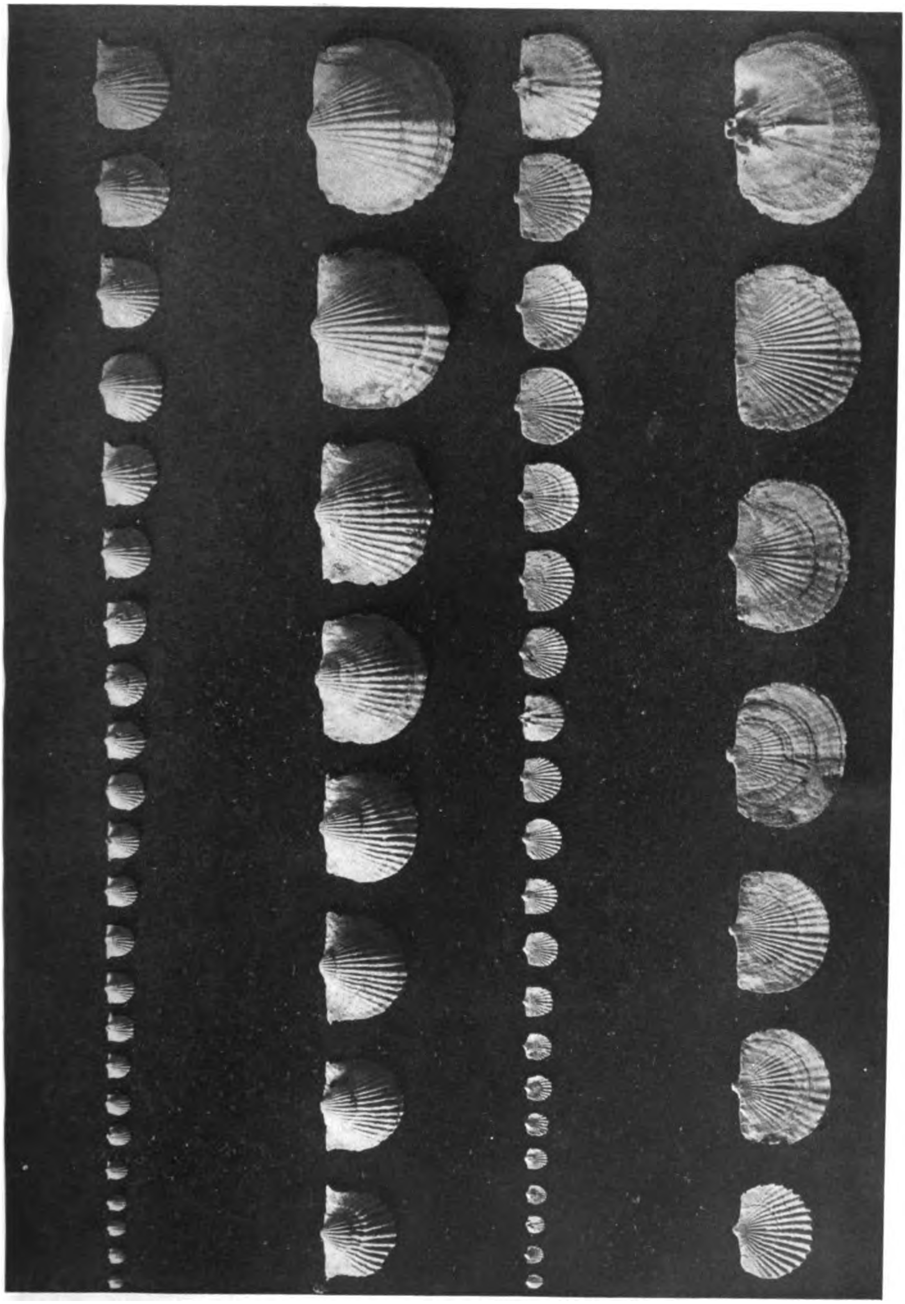
1 2 3 4

1, 2.—Spirifer mucronatus Conrad. ×1. 3, 4.—Chonetes coronatus Conrad. ×1.



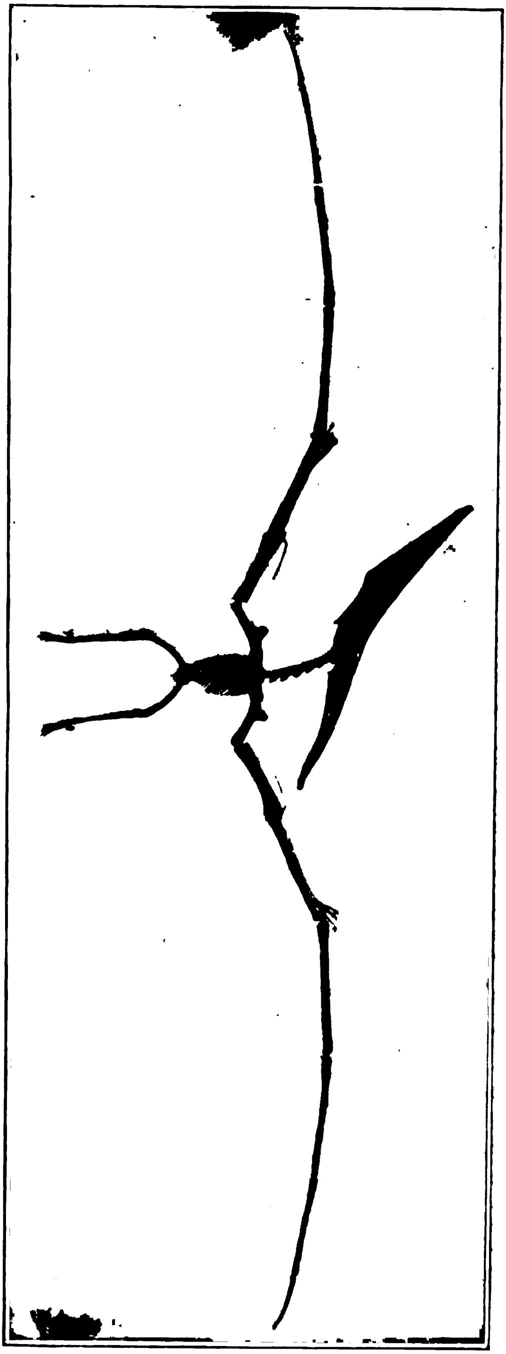
1 2 3 4

1, 2.—CHONETES ROBUSTUS Raymond. ×2. 3, 4.—STROPHALOSIA TRUNCATA Hall. ×2.



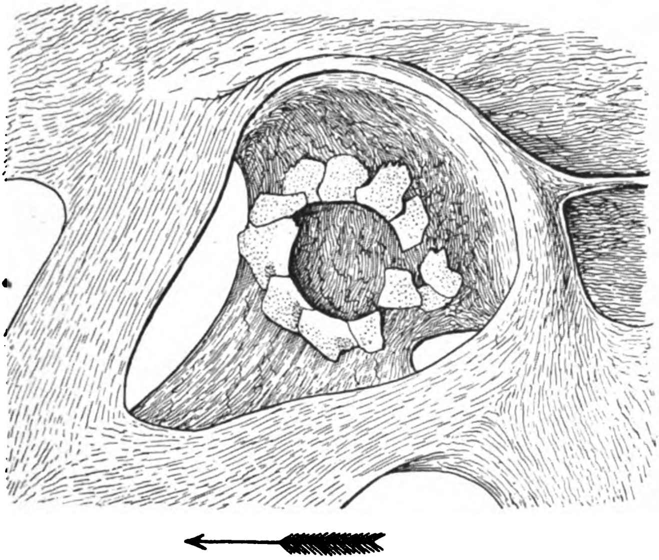
1 2 3 4

TROPIDOLEPTUS CARINATUS Conrad.



Restoration of Pteranodon longiceps Marsh.
One twenty-fourth natural size.

1



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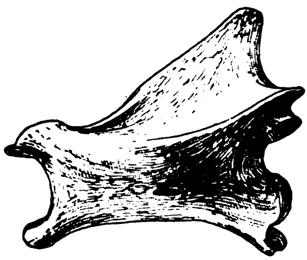

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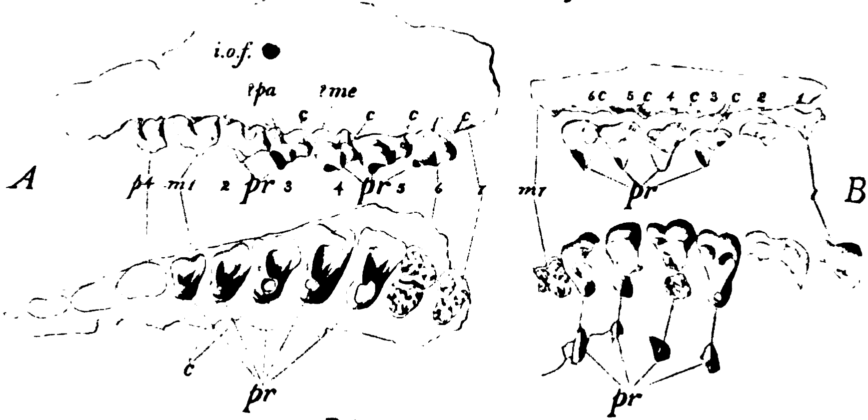
PTERANODON Marsh.

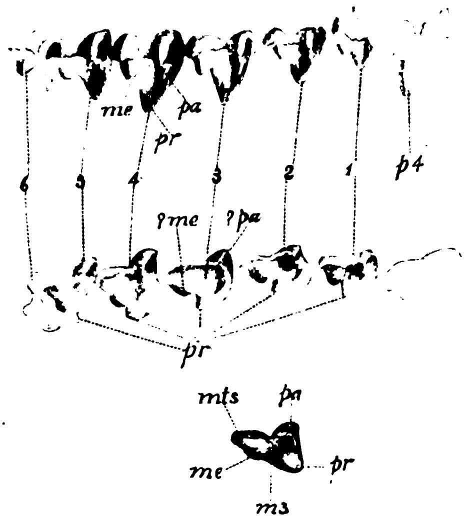
1

External or maxillary view.



Palatal or internal view.

2



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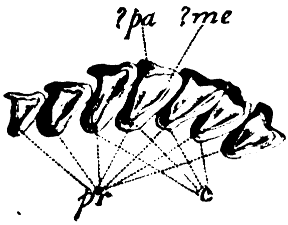


THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXX.—*Recent Changes in the Elevation of Land and Sea in the Vicinity of New York City;* by GEORGE W. TUTTLE.

THE late Professor George H. Cook, long identified with the Geological Survey of New Jersey, read an important paper at the Montreal meeting of the American Association for the Advancement of Science, August 13th, 1857, "On the subsidence of the land on the seacoast of New Jersey and Long Island,"* in which he stated that "an attentive examination of these facts has led me to the conclusion that a gradual subsidence of the land is now in progress throughout the whole length of New Jersey and Long Island, and from information derived from others I am inclined to think that this subsidence may extend along a considerable portion of the Atlantic coast of the United States."

The evidence on which Professor Cook based this conclusion was mainly of a geologic nature, and consisted of, 1st, submerged forests and buried timber found in the marshes and along the coast below tide level; 2d, numerous Indian shell heaps which have been found below tide level; 3d, the extension of the marsh on the upland, verified by many old residents, and by the dying out of cedar trees on the margin; 4th, less fall of water at any stage of the tide available to operate the waterwheels of mills on tidal streams near the sea.

It was the opinion of a number of mill operators, that within their memory the loss of head available to operate their wheels was of such an amount as would denote the sinking of the land at the rate of two feet per century. Besides, sluices in banks protecting meadow land, built about 150 years ago, were found three feet below tide level and useless for their intended purpose.

Professor Cook's estimate of the amount of subsidence of the

* This Journal, 2d Series, xxiv, 1857, p. 341.

land, which has been quoted by many authorities, rests on the above evidence, and is manifestly open to doubt and uncertainty, as he recognized when he wrote in his 1885 report, that "we find conclusive evidence of a general subsidence of the coast, or rise of water level to an extent of from ten to twenty feet within a short period of geologic time, but at a rate which is not quite definitely established." Professor Cook furthermore stated in his report of the Geology of New Jersey in 1868, that "this movement is one of a series which has occurred on our coast by which the line of water level has been alternately elevated and depressed, the whole range being confined within twenty feet."

Others have since frequently expressed the same ideas, but as they probably made use to a large extent of Professor Cook's opinions and evidence, it will be needless to quote them.

The self-registering tide gauge had only recently been made use of when Professor Cook read his paper, and tidal observations could not be obtained to determine the rate of subsidence, but since that date long series of tidal observations have become available, and it is proposed to develop in this paper what such observations in New York Harbor can tell as to the relative changes in the elevation of earth and sea in the vicinity.

The tidal observations at New York, which are of importance, start from the year 1853, when a self-registering tide gauge was put in operation by the Coast Survey at Governor's Island, and maintained up to and including the year 1879, when the series terminated. We also have the records of a self-registering gauge maintained by the Coast and Geodetic Survey during the years 1876–92, at Sandy Hook, N. J., records of self-registering gauges of the Department of Docks and Ferries from 1888–1903, at Pier A, West 57th St., and from 1894–1903 at East 24th st., in New York City, besides the record from a self-registering tide gauge of the Coast and Geodetic Survey at Fort Hamilton, for the years 1893–1902.*

The observations at Governor's Island were all referred to B. $M._1$† which was established about the year 1853 by the Coast Survey and is still in existence. Levels were run from this bench mark to other benches, in 1875 and again in 1886. The differences found at those times were checked in 1898 and 1900 and found correct, so that we may be confident that since 1875 B. $M._1$ has not settled or been otherwise disturbed.

The datum plane used in this paper is mean low water—

*** The writer is indebted to the U. S. Coast and Geodetic Survey and to the Department of Docks and Ferries, New York City, for tidal data not hitherto published.**

† For description see C. and G. S. Report 1887, app. 14, p. 298.
" " 1899, app. 8, p. 555.

M. L. W.—at the Battery as used by the Department of Docks and Ferries which is known as Battery datum, and is 2·186 feet below the datum plane of the Coast and Geodetic Survey in their levelling operations in the vicinity of New York City.*

The elevation of B. M.[1] from the above Coast and Geodetic Survey levels is 14·203 feet, and from ordinary levels run directly from the Battery to Governor's Island the elevation 14·160 was obtained. We shall adopt the former value in the succeeding work.

The following is the record of the observations at Governor's Island for each year.

Year.	Half tide level above zero of staff.	Half tide level above Battery datum.	
1846	8·32 ft.	....	
1847	10·31	....	
1848	13·12	....	
1849	12·92	....	
1850	14·16	....	
1851	12·20	....	
1852	10·51	....	
1853	5·30	1·920 ft.	Probable elevations (1853–1869)
1854	5·07	1·690	
1855	5·32	1·940	
1856	7·507	1·778	
1857	7·640	1·911	
1858	7·591	1·862	
1859	7·616	1·887	
1860	7·575	1·846	
1861	6·580	1·921	
1862	6·494	1·835	
1863	6·498	1·839	
1864	6·570	1·911	
1865	6·476	1·817	
1866	6·468	1·809	
1867	6·615	1·956	
1868	6·557	1·898	
1869	6·435	1·776	
1870	4·620	1·961	
1871	4·472	1·813	
1872	4·468	1·809	
1873	4·516	1·857	
1874	4·358	1·699	
1875	4·40	1·741	
1876	4·46	1·801	
1877	4·56	1·901	
1878	4·68	2·021	
1879	4·64	1·981	

* See appendix 14, Report of Coast and Geodetic Survey, 1887.

The above series of tidal observations from 1870–79 were carefully examined for use in determining the mean sea level—M. S. L.—in New York harbor* and these values resulted:

Year.	Mean sea level above zero of staff.	Mean sea level above Battery datum.
1870	4·692 ft.	2·033 ft.
1871	4·545	1·886
1872	4·533	1·874
1873	4·612	1·953
1874	4·410	1·751
1875	4·505	1·846
1876	4·540	1·881
1877	4·630	1·971
1878	4·751	2·092
1879	4·688	2·029

The zero of the tide staff at Governor's Island was found by levelling to be 16·899 ft. below B. $M._1$ in 1871–2 and 16·826 in 1875. Consequently the mean of these two values, 16·862 ft., has been adopted as the correct value for the series of observations 1870–79.

The elevations of half tide level†—H. T. L.—from 1853 to 1869 are subject to considerable uncertainty owing to changes in the elevation of the zero of the tide staff, of which no record appears to have been made. Such changes must have taken place in 1856, 1861, and 1870. In 1853 the zero of the tide staff was recorded as 17·00 ft. below B. $M._1$, but this location does not harmonize with the succeeding observations and there is much evidence to contradict it.

We determine the probable elevations of H. T. L. at Governor's Island for the years 1861–69, by making the average H. T. L. for the four years 1866, '67, '68, and '69 have the same elevation as the average for the four years 1870, '71, '72, and '73: the elevations of H. T. L. for the years 1856–60 are fixed by giving the average of the observations for 1857, '58, '59, and '60, the same elevation as those of 1861, '62, '63, and '64; and finally we make the average H. T. L. for the three years 1853–55 the same as the average of the three years 1856–58. Very nearly the same values are arrived at if we start with the elevation 14·51 ft. of B. $M._1$ above M. L. W. given in the Coast Survey Report for 1853. We also observe that the series of 1861–1869 shows no tendency toward increased elevation with the time, and for that reason they seem to confirm our location of the 1853–55 observations.

These elevations are still further shown to be the most probable ones, from the fact that in 1879 the elevation of B. $M._1$

* Coast and Geodetic Survey Report for 1899, p. 404.
† Which is the average of high and low tides.

was given as 14·6 ft. above M. L. W. "from the observations of 1853 verified in 1873"; and that the observations of H. T. L. at Boston from 1853–5 and 1870–3 have substantially the same relative elevations and yearly fluctuations.

From October 2d to 30th, 1886, a series of comparative tidal observations were carried out at Governor's Island and Sandy Hook, and the resulting M. S. L. corrected for annual inequality above zero of staff at Governor's Island was 4·200 ft., with zero of staff at that time 16·43 ft. below B. M.,, making M. S. L. 1·973 ft. above Battery datum.

We next have the tidal observations at Sandy Hook, which are as follows:

Year.	M. S. L. and H. T. L. above Sandy Hook datum.		Equivalent H. T. L. at Governor's Island above Battery datum.
1876	6·74	M. S. L. from hourly heights	1·774
1877	6·90		1·934
1878	7·06		2·094
1879	6·87		1·904
1880	6·84		1·874
1881	6·89		1·924
1882	6·90	H. T. L. from high and low waters (values in parenthesis partly estimated)	1·934
1883	7·02		2·054
1884	(7·17)		2·204
1885	(6·82)		1·854
1886	(6·90)		1·934
1887	6·91	M. S. L. from hourly heights	1·944
1888	7·00		2·034
1889	7·13		2·164
1890	7·05		2·084
1891	7·09		2·124
1892	7·05		2·084

The observations made at Sandy Hook were referred to a plane 17·63 below B. M. T.,* and are reduced to Battery datum by means of the simultaneous observations for the four years 1876–1879 at Governor's Island and Sandy Hook.

While spirit levels have been taken between Sandy Hook and Governor's Island, yet, owing to the considerable distance of the run, they are probably in error more than levels derived from the simultaneous tidal observations.

The levels derived from the four years of tidal observations agree almost precisely with the levels obtained from the simultaneous tidal observations in October, 1886, and are more suitable to reduce the Sandy Hook observations to simultaneous ones at Governor's Island than the spirit levels. From the spirit levels of 1887 as revised in 1899, the elevation of B. M.

* Described in C. and G. S. Report for 1887, appendix 14.
" " " 1899, page 472.

Governor's Island, above B. M. T. Sandy Hook was 1·361 ft., while from the simultaneous tidal observations of October, 1886, the difference was 1·468 ft., and from the tidal observations of 1876–9, 1·472 ft. This latter difference has been adopted in the reduction.

The observations at Sandy Hook have to be reduced to the equivalent values of half tide level at Governor's Island, which for the ten years 1870–79 was ·067 ft. lower than mean sea level, and consequently the elevations have been corrected by this amount in the column "Equivalent H. T. L. at Governor's Island above Battery datum."

The tidal records at Governor's Island from 1870–79 are particularly important in this investigation, and while the observations appear to be satisfactory, the frequent change of staffs make it desirable to have an independent check on their accuracy which we have in the observations at Sandy Hook in 1876–79, taken in connection with the levels obtained from the simultaneous tidal observations in October, 1886.

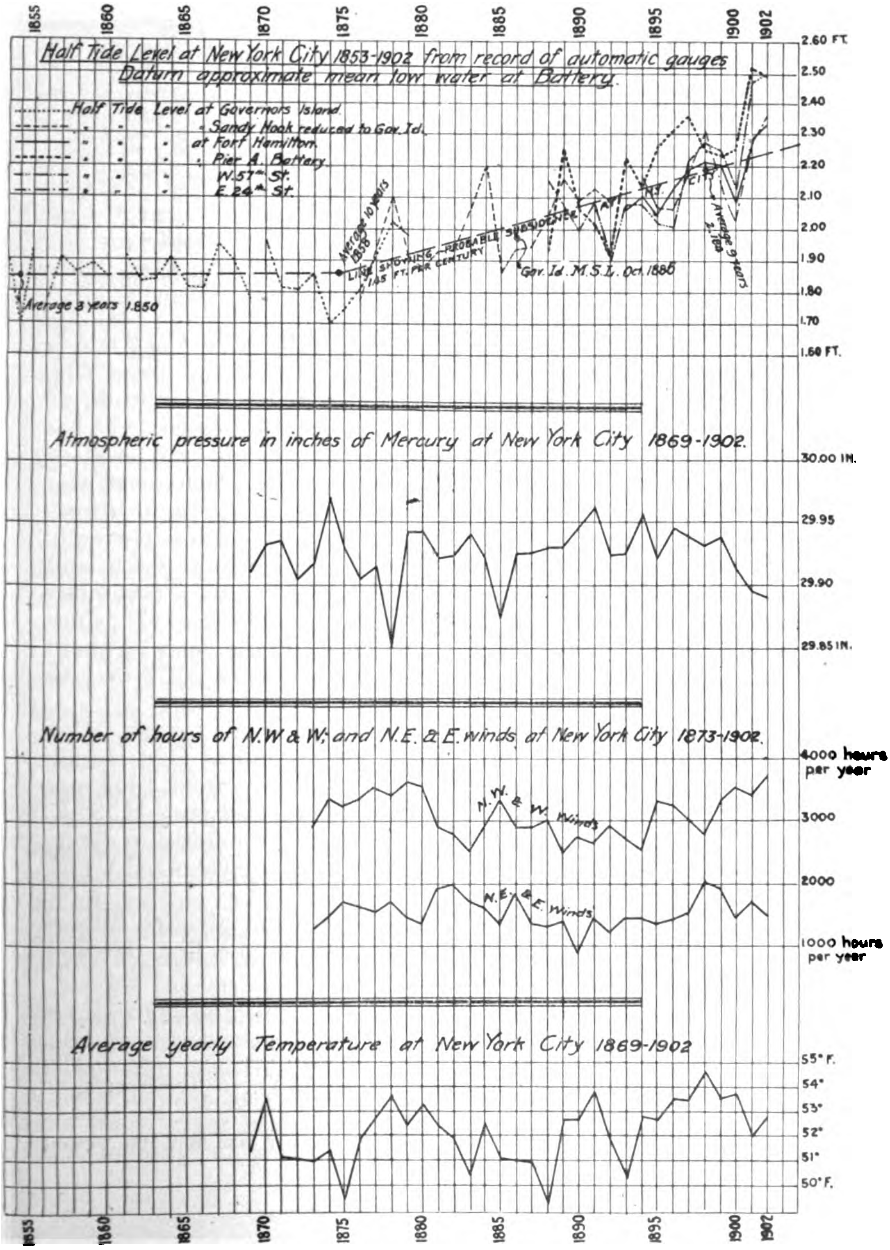
We next have a series of tidal observations at Fort Hamilton, N. Y., from 1893–1902, as follows:

Year.	H. T. L. above zero of staff.	H. T. L. above Battery datum.
1893	5·815 ft.	2·067 ft.
1894	5·885	2·137
1895	5·785	2·037
1896	5·875	2·127
1897	5·945	2·197
1898	5·960	2·212
1899	5·955	2·207
1900	5·820	2·072
1901	6·030	2·282
1902	6·085	2·337

The zero of the gauge at Fort Hamilton was 42·194 ft. below B. M. L. (destroyed in 1901), and 17·951 ft. below B. M., at Governor's Island, according to the Coast and Geodetic Survey levels of 1887. Two independent determinations of this difference in elevation have since been made, one in 1898 of 17·971 ft., and in 1900 of 18·019 ft. The 1887 value has been adopted, however, in the reduction of the staff readings to Battery datum.

Besides the above observations of the Coast and Geodetic Survey, we have the following tidal records of the Department of Docks and Ferries, all referred to Battery datum.

Diagram showing the yearly averages of Half Tide Level at New York City and the corresponding yearly averages of the principal meteorological phenomena.



	Half tide level above Battery datum.		
	Pier A.	West 57th St.	East 24th St.
1889	2·273 ft.	2·079 ft.	....
1890	2·063	1·990	....
1891	2·012	2·082	....
1892	1·910	1·902	....
1893	2·232	2·075	....
1894	2·133	2·075	2·164 ft.
1895	2·265	2·018	2·067
1896	2·314	2·003	2·053
1897	2·359	2·212	2·173
1898	2·258	2·278	2·301
1899	2·230	2·245	2·127
1900	2·250	2·127	2·012
1901	2·514	2·461	2·274
1902	2·490	2·492	2·361
1903	2·343	2·433	2·295

The yearly averages of half tide level at New York which have been given, are plotted in the diagram on page 339. They show a continual oscillation, having an amplitude of nearly 0·3 ft., about an average value which since 1875 has uniformly increased. These oscillations when considered in relation to the accompanying meteorological phenomena, also represented in the diagram, are seen to be mainly due to atmospheric pressure and winds. They are more or less perfectly eliminated by taking the average for five or more years, and when thus eliminated the observations appear to show that mean sea level remained nearly stationary from 1853 to 1875, since which time it has been rising relatively to the land by about 1·45 ft. per century. The rate of change since 1875 may be obtained in the following different ways.

(1) From ten years' observations at Governor's Island, 1870–79, the elevation of M. S. L. was 1·932 ft., and at Fort Hamilton the average elevation of H. T. L. from 1893–1902 was 2·165 ft.; allowing 0·03 ft. as the difference between M. S. L. and H. T. L. at Fort Hamilton, we have an increase in elevation of H. T. L. of 0·26 ft. in twenty-three years, or 1·1 ft. per century.

(2) The observations at Fort Hamilton alone, give the following result by taking the average H. T. L. of the first five and last five years of the series:

H. T. L. 1893–97 elevation	....	2·108 ft.
H. T. L. 1898–1902 "	....	2·223

An average elevation of H. T. L. of ·115 ft. in five years, or 2·30 ft. per century.

(3) The tidal observations at Pier A for the last ten years,

1893–1902, give 2·304 ft. as the elevation of H. T. L. at Pier A, while H. T. L. at Governor's Island 1870–79 was 1·858 ft., an increase in the elevation of H. T. L. of ·446 ft. in twenty-three years, or 1·94 ft. per century.

(4) The observations at Governor's Island 1870–79 give

Elevation of M. S. L. 1870–74 ..... 1·899 ft.
Elevation of M. S. L. 1875–79 ..... 1·964

An increased elevation in M. S. L. of 0·065 ft. in five years, or 1·30 feet per century.

(5) The observations at Sandy Hook for the seventeen years 1876–1892 give:

Elevation of M. S. L. 1876–1881 ..... 6·883 ft.
Elevation of M. S. L. 1887–1892 ..... 7·038

An increased elevation in M. S. L. of 0·155 ft. in eleven years, or 1·41 ft. per century.

(6) The observations for the fourteen years 1889–1902 at Pier A, when taken by themselves, give:

Elevation of H. T. L. 1889–1895 ..... 2·127 ft.
Elevation of H. T. L. 1896–1902 .... 2·345

An increased elevation in H. T. L. of 0·218 ft. in seven years, or 3·1 ft. per century.

(7) The average of the observations of H. T. L. for the ten years 1870–1879 at Governor's Island, compared with all the above mentioned observations at New York for the nine years 1894–1902, shows that H. T. L. has risen ·326 ft. in twenty-two and one-half years, or at the rate of 1·45 feet per century.

(8) The Department of Docks and Ferries of New York City found it necessary in 1898 to raise their plane of mean low water (to which soundings are reduced) 0·24 ft. above that in use since 1872; and the U. S. Engineers in 1900 raised their plane of mean low water 0·32 ft. above that used in 1872.

On account of the many disturbances to which tidal observations are subject, the frequent change of tide staffs in some cases, and the settlement of bench marks, it is necessary to use considerable caution in the interpretation of the observations, and all possible checks should be used. Only when independent determinations show a reasonable agreement, can we feel sure of the result arrived at.

Besides the errors which may occur in the measurement of the elevation of mean sea level, it is subject to changes from many causes, among which may be mentioned changes in atmospheric pressure, winds, temperature, various tidal components having periodicities ranging from six hours to nineteen years, river outflow, evaporation, changes in ocean currents, melting of polar snow and ice, changes in salinity,

detritus carried into the sea by rivers, and the wearing away of shores, as well as changes in the position of the earth's axis and speed of rotation.

High and low waters only were measured in most of the observations, and consequently H. T. L., which is the mean of the above quantities, has been given in the tables, except in a few instances.

In general M. S. L. obtained from hourly ordinates, which determines a level surface, differs from H. T. L. to a small extent, depending in amount on the shape of the tide wave. In deep water this difference is usually quite small, but in shallow water, or where the tide wave is obstructed, it requires to be taken into account.

It has been computed from the tidal constants that M. S. L. is 0·01 ft. above H. T. L. at Sandy Hook, and 0·067 ft. above at Governor's Island. The differences are about the same at Pier A, West 57th st., and East 24th st., as they are at Governor's Island, so far as present information goes, and at Fort Hamilton the difference is estimated to be about 0·03 ft. The Sandy Hook observations, only, have been corrected to H. T. L. at Governor's Island in the above tables.

The settlement of bench marks would make the sea appear to rise in relation to the land by the entire amount of the settlement. Consequently all bench marks should be carefully checked to guard against any change, and this has been done in the case of B. $M._1$ and B. M. L. mentioned above.

The accuracy of the tidal averages of H. T. L. obtained from an automatic tide gauge varies somewhat with the type of the instrument employed, and the attention given to it. The results are most accurate where the tidal range is small, and the working scale of the gauge large. An examination of the yearly means of the various tidal observations goes to show that the yearly averages of half tide level should not have a probable error greater than 0·05 ft., although the maximum error may be nearly three times as great. The greater part of this probable error is due, however, not to the inaccuracy of the tide gauge, but to fluctuations of the mean sea level from meteorological causes.

When we examine the daily changes of mean sea level in New York Harbor, we find that they are mainly determined by the velocity and direction of the wind. N.W. and W. winds are the effective agents in depressing the sea level and N.E. and E. winds in raising it.* The mean level has been at times raised

* Des Barres in his charts of New York Harbor published in 1780, says, "Tides rise perpendicularly about seven ft., but are sometimes checked to such a degree by the Westerly or North Westerly winds, as to lower the water on the bar to three fathoms and one-quarter, and Easterly or North Easterly winds have frequently risen it to five fathoms."

or depressed as much as three feet from its average elevation during strong gales in the above directions.

When we pass from the daily changes to the monthly averages of mean sea level, we find a remarkable correspondence between the height of mean sea level and the movement of the northwest and west winds, while the northeast and easterly winds appear to have little effect on these monthly averages. Probably the greater and more uniform effect of the westerly winds, which has been proved by analysis for a long series of years, is due to the fact that they are the prevailing winds, last for a considerable time, have greater intensity, and are effective over large areas, while the easterly winds are more local, and changeable.

The atmospheric pressure does not usually appear to have an important share in determining the monthly values of mean sea level, except as it influences the intensity of the prevailing westerly winds.

These monthly averages show a minimum mean sea level, sharply defined in January, and a maximum mean sea level, not sharply defined in August; while the westerly winds have a maximum sharply defined in January, and a minimum not sharply defined in August. This seasonal difference in elevation of mean sea level averages 0·55 ft. By means of yearly averages we eliminate these seasonal fluctuations as well as all astronomical effects, except that having a period of 19 years, which is so small in this latitude (less than 0·2 inch) that it may be neglected.

Particularly noticeable in the tidal curves is the very considerable depression of half tide level in 1874, and the great elevation of half tide level in 1878. When compared with the curve of atmospheric pressures, it will be noticed that abnormal changes of the barometric pressure occurred in those years, which seem to show that they occasioned the tidal fluctuations.

Tidal elevations and barometric pressures at a number of stations on both sides of the Atlantic show that these atmospheric surges extended over a large area, and similarly affected all tide gauges on the North Atlantic Ocean.

In the year 1900 a marked depression in half tide level is shown by the New York observations. As this same depression was observed at Fernandina, Fla., and other points, we may presume that it took place along the entire Atlantic Coast. At New York City, it appears to have been caused by the unusual strength of the N.W. and W. winds.

In 1901 and 1902 mean sea level at New York City rose to a height not before attained, which was probably due to the low barometric pressure prevailing during those years.

As the effect of the atmospheric pressure and winds on the sea level at any place is the integral of their effects taken over a wide area, while these observations are taken at only one point, a close correspondence is not to be expected, particularly where the locality is at the junction of continental and ocean areas, as in this case.

It has been recently found from the yearly averages of atmospheric pressure at many widely separated places, that abnormal variations of atmospheric pressure occur of considerable duration, which are apparently caused by the surging to and fro of the atmosphere. They affect a very considerable area and have a tendency to recur in periods of about three and eight years, corresponding closely with periodic variations of solar energy received by the earth.

The examination of long series of tidal observations in places scattered over the world discloses very similar periodicities, which are doubtless due in the main to the surging of the barometric pressure before alluded to, and the consequent change in the atmospheric circulation.

Tidal observations from Maine to Florida disclose a striking similarity among the changes in half tide level at all localities on the Atlantic Coast, and the same phenomena have been observed on the shores of the Baltic Sea. It appears quite certain that these fluctuations of yearly half tide level, nearly alike in direction and amount, are due mainly to changes in the mean annual barometric pressure, and the accompanying changes in wind velocities. These periodic fluctuations, never more than a few years in duration and very much alike in extent and direction at all the points embraced in a large area, evidently are changes due entirely to the sea, and can in no way be considered as showing a change in the absolute elevation of the land.

On the other hand, there are no changes in the meterological phenomena which will account for a continuous increase of half tide level for a series of years, such as have been observed at New York from 1875 to 1902, at Boston for the same period, and at Penobscot Bay from 1870 to 1885. Neither will such changes account for the continuous depression of sea level shown by the series of observations at Stockholm, Sweden, commencing in 1774, and verified by numerous observations along the Swedish coast of the Baltic Sea, where it has been found that the land has risen nearly two feet relatively to the sea, while equally reliable observations on the German coast of the Baltic Sea, dating from 1811, show no appreciable change in level.

No long period or continuous variations of atmospheric pressure, winds, temperature, ocean currents, etc., appear to exist to

explain these secular changes in mean sea level, and if such changes did occur, they could hardly explain the difference in amount and direction of the changes of sea level observed at different points. Besides, it is seen from tidal observations on the German coast of the Baltic Sea, the North Sea, and the coast of India, that no continuous change in ocean level has occurred in those places, which would probably be the case if there had been any great or long continued change in absolute ocean levels elsewhere.

We must conclude then, except for minor variations due to meteorological conditions, that it is the land and not the sea which is changing in elevation.

Most of the geological evidence appears to show that the movement of the land relatively to the sea in recent geologic times has been of a cyclic character and confined within narrow limits. There is little geologic evidence to be found in the vicinity of New York of a definite character to indicate depression. It is true that marsh sod can be found outshore from the beach, and below mean sea level; that cedar trees die out on the shore, and that peat bogs and stumps of trees have been found in many places below sea level. These phenomena are to be explained, however, by the inroads of the sea during storms, and by wave action; as well as by the compression and consolidation of the marsh land, which has been known to sink as much as three feet when drained, or loaded with sand. As we leave the shore these apparent evidences of subsidence disappear and in places thoroughly protected from the sea few or none of them are found.

It does not appear from the evidence presented by tidal records, or from historic or geologic evidence, that our sea-coast is in any immediate or serious danger from subsidence of the land, for almost without exception the longest records show the least change, and were it not for the power and efficiency of modern dredging machinery the shoaling of harbors would probably be a more serious affair.

The tidal observations have been taken for so short a time, however, that they can only tell us what has been going on recently, and do not disprove a possible change in ocean elevation too small to be detected within the period of observation.

In conclusion it may be stated with confidence, as the result of an inspection and study of tidal observations on both sides of the Atlantic for the first time brought together,

(1st) That the mean sea level oscillates in an irregular manner, having an average period of about eight years. These oscillations closely resemble one another at many ports distant from each other, and appear to be largely due to changes in

atmospheric pressure, and the resulting changes in wind velocities.

(2d) The above oscillations compensate themselves completely in the course of time, and do not give rise to a continuous movement in a given direction.

(3d) That in addition to the above movements of the sea some ports show a more or less continuous rising of the sea relatively to the adjacent land; others a lowering of the sea level in its relation to the land, and still others maintain a constant relation between the two. These latter make it clear that except for the periodic changes noted above, the sea does not change its level, and that the relative changes are due to land movements.

(4th) At various ports the rate of change in the elevation of mean sea level referred to the adjacent land has not remained constant, but has varied in a considerable degree. All the observations show that for long periods the rate of change is less than took place in some part of that period, and the evidence is strong that the movement is not continuous, but oscillatory and confined within narrow limits.

(5th) The observations at New York City show that since 1875 the land has been subsiding relatively to mean sea level by about 1·45 ft. per century, but from the establishment of the self-registering tide gauge in 1853 to that date, little or no change had occurred, and it is improbable that the present rate of subsidence will be continued indefinitely.

Art. XXXI.—*On the Geology of Brome Mountain, one of the Monteregian Hills*; by John A. Dresser.

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In the western part of the province of Quebec, the basin between the Appalachian Hills on the southeast and the southern edge of the old, but now elevated, Laurentian peneplain* at the northwest, is about eighty miles wide. It is occupied by rocks of Paleozoic age in which the geological scale is represented from Cambrian to Lower Devonian, both inclusive. This basin has a nearly level surface except for the presence of a series of hills, eight in number, known as the Monteregian Hills.† Six of these, namely, Mount Royal, Montarville, Beloeil, Rougemont, Yamaska and Shefford, rise at somewhat regular intervals of about ten miles, and in a nearly east and west line. They thus extend for a distance of fifty miles eastward from Mount Royal and from the city of Montreal at its base. Brome Mountain and Mount Johnson are respectively two and a half and six miles south of Shefford and Beloeil. Mount Royal, which is probably the lowest, is 769·6 feet above mean sea level, while Shefford has an altitude of 1,600 feet. Rougemont, Montarville and Yamaska have not yet been determined. The others are intermediate between the heights given, Brome reaching an altitude of 1500 feet.

Considered physiographically, these hills are of residual origin, having been etched into their present relief by the extensive denudation of the region by which not less than one thousand feet of the plain have been removed. The composition and texture of the rocks which compose these hills have evidently offered so much greater resistance to denuding agencies than was afforded by the surrounding strata as to give the hills their present elevation. Hence they are hills of the butte type.

Reports on the geology of the district, with more or less attention to the petrography of these hills, have been made by Dr. T. Sterry Hunt in 1858, by Sir William Logan in 1863 and by Dr. R. W. Ells in 1894.‡

Dr. F. D. Adams in 1903§ made a general review of these hills and proposed for them the name "Monteregian", (Mons Regius), and also gave a detailed description of Mount Johnson. Fig. 1 of this sketch is reproduced from Dr. Adams' paper. The writer is also indebted to Dr. Adams for valuable advice on many points in connection with this investigation.

* Dr. A. W. G. Wilson, Journal of Geology, vol. xi, No. 7, "The Laurentian Peneplain."

† Dr. F. D. Adams, Journal of Geology, vol. xi, No. 3. "The Monteregian Hills—a Canadian Petrographical Province."

‡ Geological Survey of Canada. § Op. cit.

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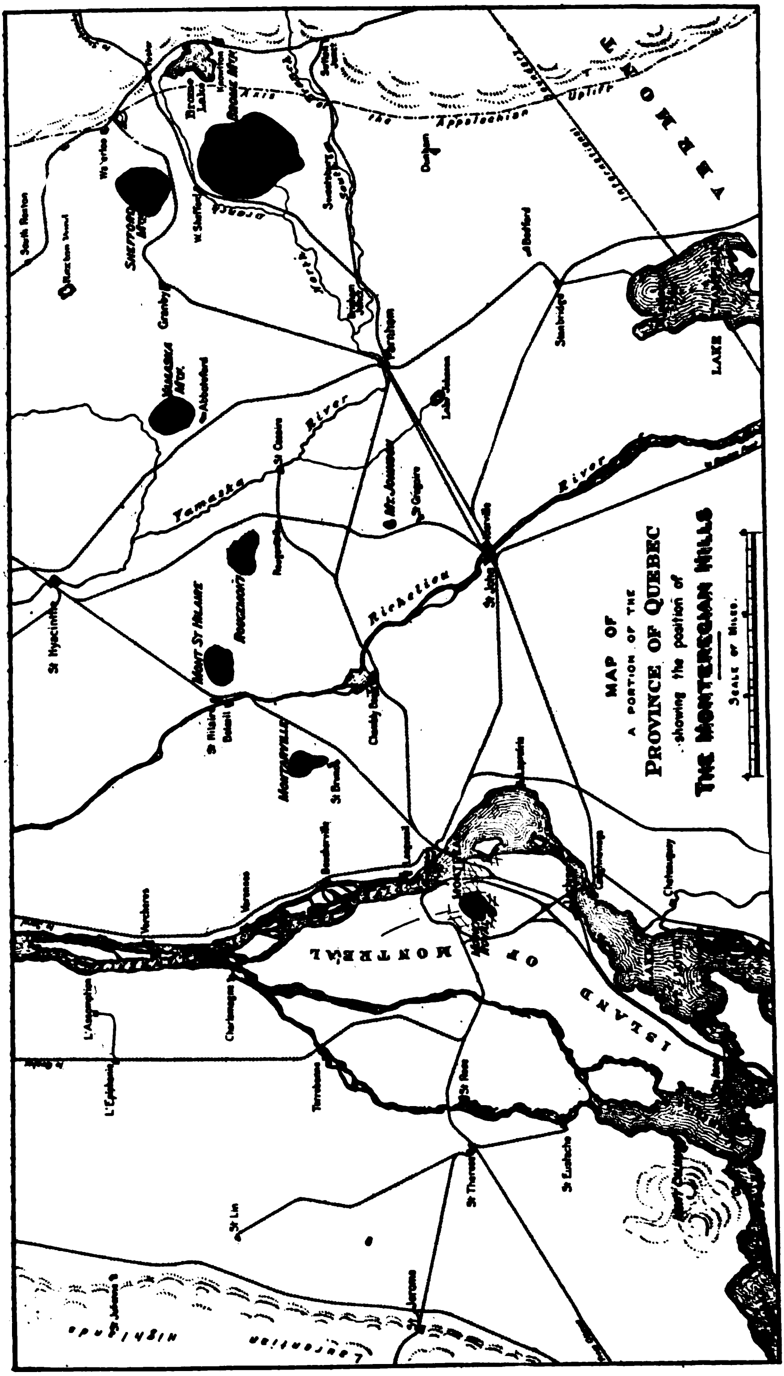

MAP OF
A PORTION OF THE
PROVINCE OF QUEBEC
showing the position of
THE MONTEREGIAN HILLS
SCALE OF MILES
VERMONT
LAKE
Axis of the Appalachian Uplift
Yamaska River
Richelieu
River
ISLAND OF MONTREAL
Laurentian Highlands
Brome Lake
St Hyacinthe
St Johns
Granby
Farnham
Chambly Basin
Mont St Hilaire
Rougemont
Montarville
Shefford Mt.
Yamaska Mt.
Brome Mt.

In 1901 the present writer completed a report* on Shefford Mountain which is now in press, and published a résumé of it in the American Geologist for October of that year (vol. xxviii).

The above mentioned investigations have shown that the Monteregian Hills are of igneous origin and are intrusive in their relations to the strata surrounding them. As a petrographical province they are distinguished by two main rock types, one representing a basic magma of the essexite class in the Rosenbusch classification—the other, various types of alkali-syenite. In structure Mount Johnson, and probably Mount Royal, are true volcanic necks, while Shefford has been found to be a laccolite.

It is the purpose of the present paper to outline the main features of Brome Mountain, and to indicate its general relation to the other hills of the Monteregian series that have been thus far studied.

Brome Mountain is the largest hill of this series. It comprises an area of about thirty square miles in the counties of Brome and Shefford. Together with Shefford Mountain, which stands two and a half miles to the north, and is next to it in size, Brome is the most easterly of the Monteregian Hills. In form it is rudely circular. The central portion, about Brome pond, is a nearly level basin two and a half by one and a half miles in extent, and overlain by heavy beds of post-glacial clay. The interior basin has an average altitude of about five hundred feet above sea level, or only a little above the country surrounding the mountains; while the basin is encircled by a rim of hills which rise to heights of from six hundred to one thousand feet above the surrounding plain, or one thousand to fifteen hundred feet above the sea. "Pine Mountain" is the highest point.

In common with the other hills of the Monteregian series, Brome is an igneous mass intrusive through Paleozoic strata. The latter belong to the Sillery division of the Cambrian system on the north, east, and south sides of Brome mountain, and on the west to the Mystic series (D2*b*) of the upper Chazy†.

The latest time at which the intrusion could have taken place is also indicated, though less definitely, by the fact that the igneous rocks are somewhat foliated, and show in places an incipient schistose structure. This is parallel in direction with the schistosity of the surrounding sediments, though much less in degree, and represents a late stage in the folding of the Appalachian uplift. As this was not shared in by the Permo-Carboniferous of the maritime provinces, Brome mountain was formed after the deposition of the upper Chazy sediments and before the close of the Carboniferous period.

* Geological Survey of Canada, vol. xiii, part L.
† Dr. R. W. Ells, Annual Report of the Geological Survey of Canada, 1894.

This age limit virtually agrees with that of the adjacent intrusion of Shefford mountain which shows similar dynamic metamorphism, but cuts slightly later strata, viz., The Farnham black slates (D3*a*), a division of the lower Trenton. The latter, however, do not occur at Brome.

The presence of numerous sedimentary outliers which have been invaded and otherwise altered by the igneous rocks beneath, together with the general character of those rocks, and the absence of any tufaceous material, seems to indicate that Brome mountain is an uncovered laccolite and has never been an active volcano. The evidences of a similar structure at Shefford mountain are most conclusive, and as the distance between the mountains is only two and a half miles, which is less than the smallest diameter of either, they are probably parts of a single laccolite. The correspondence of the rocks in the two masses also favors this view.

Petrography.

The igneous rocks of which Brome mountain is essentially composed belong to three principal types, two of which certainly are the products of separate irruptions, and the third possibly so. The rock of the earliest intrusion is of the Essexite family, according to the Rosenbusch classification, or in the Quantitative Classification* it is a Hessose.

The second is of a syenitic character ranging from Nordmarkite to Nepheline syenite. It is Nordmarkose in the Quantitative Classification. The third, which is of comparatively small extent, is a porphyritic rock which from its microscopic and chemical character is classed as a phyro-laurdalose. Their distribution is shown on the accompanying figure (2).

The nordmarkose distinctly cuts the hessose, but the contact of the laurdalose with the nordmarkose, which completely surrounds it, is everywhere drift-covered so that conclusive evidence of their relations could not be obtained.

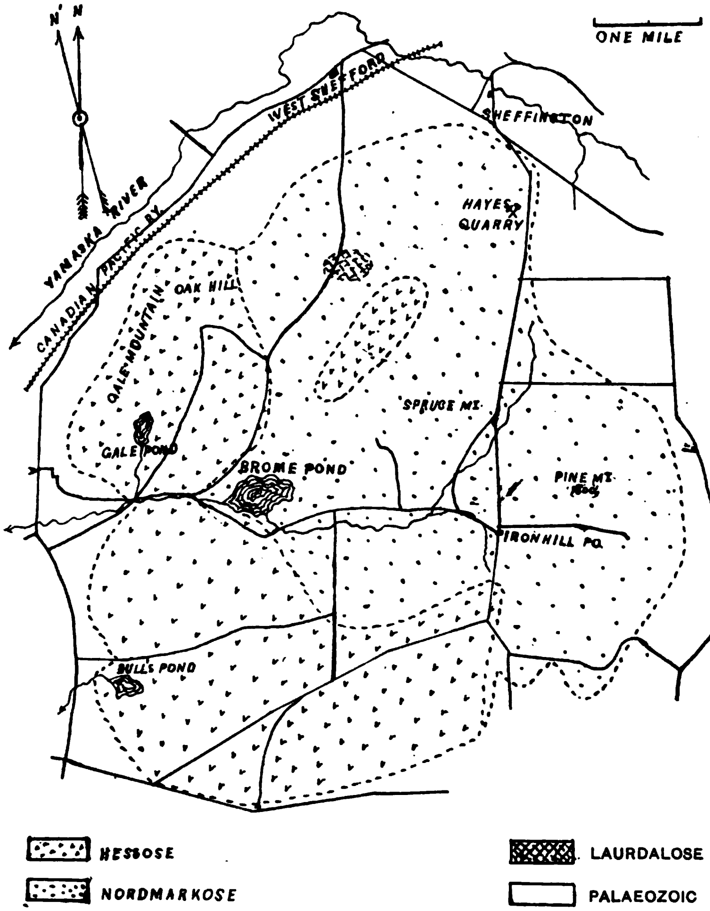
Hessose.—This is a massive rock, gray in color, and weathering to a dull brown. Its structure is granitoid and the texture medium. Feldspar and small amounts of dark minerals, chiefly hornblende, mica, and iron ore, can be seen by the unaided eye.

In the thin section feldspar is found to constitute fully 90 per cent of the rock, in parts that are considered typical, the remaining constituents being pyroxene, olivine, and biotite with accessory magnetite and apatite. Hornblende in many cases occurs quite as abundantly as pyroxene, but in other parts of the rock is entirely wanting. The structure in general is hypidiomorphic granular.

* "Quantitative Classification of Igneous Rocks," Cross, Iddings, Pirsson and Washington, The University of Chicago Press, 1903.

The feldspar is chiefly a plagioclase, which is twinned according to the albite law in broad lamellæ upon which it extinguishes symmetrically an angle of 40 degrees or more. It is bytownite, or basic labradorite. A few rather large crystals of microperthite are the only other feldspathic constituents seen.

2



Map of Brome Mountain, Quebec, Canada.

The hornblende is trichroic, the scheme of absorption being $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$, with $\mathfrak{b}$ nearly equal to $\mathfrak{c}$. The color ranges from chestnut to yellowish brown. The maximum extinction angle, $\mathfrak{c} \wedge c$, that was observed was 20 degrees.

The principal variety of augite present is slightly dichroic. Sections having $\mathfrak{b}$ or $\mathfrak{c}$ parallel to the plane of the polarizer of

the microscope are gray, or grayish green; those with *a* in the same position are flesh-colored. In a few instances grains of another variety of augite are possibly present, but the amounts are too small to admit of satisfactory determination.

Olivine, where present, is colorless, and is serpentinized along cracks in the primary mineral.

Biotite occurs in irregular areas having imperfect crystallographic outlines.

Magnetite, sphene, apatite, and occasionally a little nepheline in a decomposed condition are also present but present no features worthy of further notice.

An analysis by Mr. M. F. Connor of the Geological Survey of Canada gave the result I in the following table; II is an analysis of Åkerose (Essexite) from Shefford mountain, also by Connor; III, of Andose (Essexite) from Mount Johnson, and IV, the original Essexite from Salem, Mass.

	I.	II.	III.	IV.
SiO_2	44·00	53·15	48·85	47·94
Al_2O_3	27·73	17·64	19·38	17·44
Fe_2O_3	2·36	3·10	4·29	6·84
FeO	3·90	4·65	4·94	6·51
MgO	2·30	2·94	2·00	2·02
CaO	13·94	5·66	7·98	7·47
Na_2O	2·36	5·00	5·44	5·63
K_2O	·45	3·10	1·91	2·70
P_2O_5	·20	·65	1·23	1·04
TiO_2	1·90	1·52	2·47	·20
MnO	·08	·46	·19	....
H_2O	·80	1·10	·68	2·04
	100·01	99·64	99·36	99·92

The calculation of the norm of I in order to refer it to its proper place in the Quantitative Classification gave the following results:

The norm of I:

Orthoclase		2·22
Anorthite		63·90
Albite		14·67
Nepheline		2·84
Diopside	$\left\{\begin{array}{l}17CaOSiO_2\\13MgOSiO_2\\4FeOSiO_2\end{array}\right\}$	3·80
Olivine	$\left\{\begin{array}{l}44MgO, \tfrac{1}{2}SiO_2\\12FeO, \tfrac{1}{2}SiO_2\end{array}\right\}$	4·30
Ilmenite		3·65
Magnetite		3·48
Apatite		·34
Water		·80
		100·00

The rock accordingly falls in

Class II,	Dosalane
Order 5,	Germanare
Rang 4,	Hessase
Subrang 3,	Hessose

(Grad-polmitic)
(Sub-Grad. premirlic)

Its actual mineral composition being practically normative, and its structure megascopically granitic, the rock is, therefore, classed as a *grano-hessose.*

2. *Nordmarkose.*—This is also a plutonic rock of medium or coarse texture and gray or reddish gray color. In the hand specimen it shows only feldspar with an occasional speck of biotite.

In the thin section feldspar is found to make up probably 90 per cent of the volume of the rock. The remaining constituents in order of relative abundance are biotite, pyroxene, hornblende, sphene, apatite. Biotite and pyroxene, and occasionally hornblende, may be ranked as essential constituents. Biotite more than equals in amount all the other constituents except feldspar. Occasionally a little nepheline is seen and in other parts a few grains of quartz. Logan mentions* the specific gravity of this rock as 2·632–2·638.

The feldspar resembles orthoclase in its general appearance, but has a mottled look, and under higher powers proves to have a fine perthitic intergrowth in the spotted areas.

These also are found to be more numerous under higher magnifying powers, apparently their extent being limited only by the power of the microscope. The feldspar is, therefore, regarded as cryptoperthite. Logan (op. cit.) reported its specific gravity to be 2·575 and gave the following analysis (V) of selected grains. VI is an analysis of cryptoperthite from Laurvik, Norway, by Gmelin, described by Brögger (Syenitpegmatitgänge, p. 524).

	V.		VI.
SiO_2	65·70		65·90
Al_2O_3	20·80		19·46
CaO	·84		·28
Na_2O	6·52		6·14
K_2O	6·43		6·55
H_2O	·50		·12
		Fe_2O_3	·44
	100·79		98·90

*Geology of Canada, 1863, p. 656.

Hornblende is green in ordinary light and shows pleochroism. It is in so small amounts, however, that the scheme of its absorption could not be satisfactorily determined.

The other minerals require no special note. Where quartz enters into its composition this rock is identical with the Nordmarkose (Nordmarkite) of Shefford Mountain. In other phases it closely resembles the Laurvikite of Southern Norway described by Prof. W. C. Brögger. Its resemblance to both is shown in the following analyses.

	VII.	VIII.	IX.	X.
SiO_2	61·77	58·88	65·43	59·96
Al_2O_3	18·05	20·30	16·96	19·12
Fe_2O_3	1·77	3·63	1·55	1·85
FeO	1·75	2·58	1·53	1·73
MnO	·08	....	·40	·49
CaO	1·54	3·03	1·36	2·24
MgO	·89	·79	·22	·65
Na_2O	6·83	5·73	5·95	6·98
K_2O	5·21	4·50	5·36	4·91
P_2O_5	·15	·54	·02	·14
TiO_2	·74	....	·16	·66
H_2O	1·10	1·01	·82	1·10
	99·97	100·99	99·74 x	99·83 ^

x SO_3	—·06	^ BaO	—·12
		SO_3	—·08
Cl	—·04	Cl	—·14

VII. Nordmarkose, Brome. Analysis by M. F. Connor.
VIII. Laurvikose, Byskoven, near Laurvik, Norway. ("Chemical Analyses of Igneous Rocks," by H. S. Washington.)
IX. Nordmarkose, Shefford. Analysis by M. F. Connor.
X. Laurvikose " " " "

The norm of VII is as follows:

Orthoclase	31·14
Albite	57·11
Anorthite	2·78
Nepheline	·28
Olivine	·62
Diopside	3·16
Apatite	·34
Ilmenite	1·37
Magnetite	2·55
	100·45

The place of the rock in the quantitative classification is as follows:

Class I,	Persalane
Order 5,	Canadare
Rang 1,	Nordmorkase
Subrang 4,	Nordmarkose

In structure it is megascopically granitic and, therefore, becomes a grano-nordmarkose. It, too, is approximately normative. The chief departure of the norm from the mode is in the alkali feldspars, which in the rock are in the form of microperthite.

Laurdalose.—This is a porphyritic rock having a greenish matrix and a few phenocrysts of light gray color.

In the microscopic section the rock is seen to be porphyritic with a felsitic base. The phenocrysts are found to be feldspar, generally of the character of that mineral in the nordmarkose. No plagioclase was certainly seen. Part of the feldspar appears to be pure orthoclase but more possesses the mottled character of cryptoperthite. Patches of granular feldspathic-looking material are also numerous and are prominent in the cryptocrystalline groundmass of the rock. Granular ferromagnesian minerals are also found in some of these aggregates.

Magnetite and apatite in small amount are also present. Sodalite appears in bluish individuals having rounded or polygonal outlines. It is perfectly isotropic, showing no pleochroism, even with a gypsum plate producing red of the first order, and yields no interference figure in condensed light. The dust-like inclusions characteristic of this mineral too are noticeable. A little chlorite and a few individuals of biotite are also seen.

	XI.	X.	XII.
SiO_2	55·68	59·96	55·65
Al_2O_3	20·39	19·12	20 06
Fe_2O_3	2·10	1·85	3·45
FeO	1·95	1·73	1·25
MgO	·80	·65	·78
CaO	1·92	2·24	1·45
Na_2O	9·18	6 98	8·99
K_2O	5·34	4·91	6·07
TiO_2	·60	·66	....
P_2O_5	·06	·14	....
MnO	·31	·49	....
H_2O	1·50	1·10	1·51
	99·83	100·17	99·21

XI. Laurdalose, Brome. Analysis by M. F. Connor.

X. Pulaskite, Shefford (Laurvikose), by M. F. Connor.

XII. Tinguaite, Hedrum, Norway (Laurdalite). Analysis by V. Schemlck. Described by W. C. Brögger. ("Chemical Analyses of Igneous Rocks," H. S. Washington.)

The norm calculated from this analysis is as follows:

Orthoclase	31·69
Albite	27·77
Nepheline	25·56
Acmite	2·31
Diopside	7·85
Olivine	·24
Ilmenite	1·06
Magnetite	1·86
Water	1·50
	99·84

It is therefore classed as follows—.

Class II,	Dosalane
Order 6,	Norgare
Rang 1,	Laurdalase
Subrang 4,	Laurdalose

The structure of this rock is both macroscopically and microscopically porphyritic.

As sodalite is one of the few distinguishable minerals in it, and is indicative of its alkaline character, it might best be designated as a sodalite-bearing felsophyro-laurdalose.

Comparison of Brome and Shefford.

When compared with Shefford Mountain the similarity of the two hills is found to be very close. In Shefford Mountain there have been three separate eruptions and the rocks thus produced in order of intrusion are very similar to those of Brome.

Shefford	Brome
1st, Akerose (Essexite);	1st, Hessose
2d, Nordmarkose (Nordmarkite)	2d, Nordmarkose
3d, Laurvikose (Pulaskite)	3d, Laurdalose

The rocks of the first intrusions in the two hills thus correspond very closely while those of the second are identical, while the third classes do not differ widely.

In point of general structure the hills are practically alike except that dikes later than the main mass of the mountain are very numerous at Shefford while they are almost altogether wanting at Brome.

Chemical Composition of Original Magma.

An effort was made to ascertain the chemical composition of the original magma which produced these rocks. The present surface exposure of the mountain may be taken as affording an average cross section of the mass. Accordingly, the relative

areas occupied by the three rock types at Brome were ascertained by placing a tracing of the map upon a sheet of square ruled paper and counting the squares occupied by each.

Taking the area of laurdalose as the unit, nordmarkose and the hessose occupy 150 and 110 units respectively. Multiplying their analyses by these coefficients of area, and dividing the sum of the products by the sum of the coefficients, the mean of the means obtained is that given as analysis XVII.

The analyses of the three related rocks in Shefford Mountain were treated in a similar manner, and the result given as analysis XIII.

But since the two mountains are to be regarded as parts of the same laccolite it is necessary to find the average of these means. This having due regard for the area of the two masses is found to be that given under XVIII.

	XVII.	XIII.	XVIII.
SiO_2	54·25	59·51	55·47
TiO_2	1·23	·78	1·13
Al_2O_3	22·14	17·90	21·17
Fe_2O_3	2·03	2·17	2·07
FeO	2·66	2·64	2·66
MnO	·12	·45	·20
MgO	1·48	1·27	1·44
CaO	6·77	3·09	5·93
K_2O	3·23	4·46	3·52
Na_2O	4·95	5·98	5·19
P_2O_5	·17	·27	·12
H_2O	·98	1·00	·99
	100·01	99·52 x	99·89

xBaO	·08
CO_2	·13
SO_3	·14
Cl	·08

A rock having the composition of the mean of Brome Mountain should be classed as follows in the Quantitative Classification:

Class I, Persalane
Order 5, Canadare
Rang 3,—— (alkalicalcic)
Subrang 4,—— (dosodic)

The mean composition of Shefford Mountain, XIII, would be classed thus:

Class II, Dosalane
Order 5, Germanare
Rang 3, Andase
Subrang 4, Andose

Such a rock would stand nearly on the line between the persalanes and the dosalanes, the ratio of the salic to the femic minerals being 85·33 : 12·40.

The average composition of the Brome and Shefford laccolite, as indicated under XVIII, would therefore give a rock which would be classed thus:

Class I,	Persalane
Order 5,	Canadare
Rang 3,——	(alkalicalcic)
Subrang 4,——	(dosodic)

This agrees with the mean of Brome, and differs but slightly from that of Shefford which stands very near the dividing line between Classes I and II, while they quite agree in the subordinate part of their classification as to Order, Rang and Sub-Rang.

The general mean of the two hills, as well as that of Brome, thus falls in a part of the scheme of the Quantitative Classification that has not yet been occupied. Being hypothetical rocks, however, they do not warrant the introduction of a new name, nor is it necessary, since their position can be otherwise definitely indicated by means of this admirable system of classification.

Art. XXXII.—*The Crystallization of Molybdenite;* by A. J. Moses.

The only satisfactory measurements of molybdenite crystals which have been made are those of Brown* upon material from Frankford, Pa. The earlier measurements of Hörnes were discredited by Kenngott's later examination and those of Knop were evidently made upon bent crystals.

The difficulties in the way of measurement are the striations upon the pyramidal faces which produce multiple and blurred images of the collimator signal and the frequent bending of the crystals as shown by grooves and ridges† upon the cleavage surface which frequently form three systems, each perpendicular to an edge of the hexagonal surface. In some cases these grooves are at many angles without any apparent law.

In a careful examination of a number of molybdenite crystals I have obtained some results which are worthy of record. In some cases, as in the Warren, N. H. crystals, the interpretation of the results may not be the correct one.

1. *Molybdenite from Enterprise, near Kingston, Ontario.*

In a quantity of material obtained from Mr. C. W. Dickson there was one doubly terminated crystal (fig. 1), about 8^{mm} across by 2^{mm} thick, the pyramidal faces of which were bright, a little curved and almost free from striations, and the terminal plane, which did not appear to be a cleavage, was bright and showed few grooves.

The crystal was attached to a gangue of pyroxene, phlogopite and pyrrhotite but projected so that it was possible to measure the angles between the basal plane and two of the pyramidal faces.

The faces did not yield single images and two separate adjustments were made for each angle with different combinations of lenses. The results, each in itself an average of four or more measurings, were:

First angle.	Second angle.
41° 21½′	41° 28′
41 53	41 02

Average of all, 41° 26′.

This corresponds to a pyramid ($20\bar{2}5$) the angle for which calculated to Brown's unit would be 41° 23′.

* Proc. Acad. Nat. Sci. Phila., 1896, p. 210.

† Brögger showed (Zeitschr. f. Kryst. x, 507, 1885) that such markings could be produced by pressure, and Mügge attributed them (N. J. f. Min. 1898 i, 109) to translation along the plane 0001 perpendicular to the markings.

2. *Molybdenite from Aldfield, Quebec.*

A specimen purchased from the Foote Mineral Co. showed a barrel-shaped crystal (fig. 2), the basal plane 7×5^{mm}, thickness 4^{mm}. The cleavage surface was not crumpled and was free from grooves and ridges but was pitted with little etch figures of not very definite shape. The pyramidal planes were striated.

When adjusted on the two-circle goniometer by use of this pitted cleavage surface, it was found that, at intervals of closely 60° of the vertical circle, zones were obtained which yielded images of the collimator signal for two different positions, both positions corresponding to a bright illumination of the entire face. That is, the striations in this crystal are due to an oscillation between two forms and not to gliding or translation, this being further proved by the absence of grooves and ridges on the cleavage.

In each zone one of the two images corresponded to ρ approximately 90°. The crystal was therefore readjusted until these were exactly 90° and the results for the second image thereafter in four zones were:

ϕ	ρ	
0°	77°20′	Dull image
59°41′	77 21	Single image
120 09	77 10	Brighter of two
180 10	77 22	" " "
	Average ρ=77° 18′.	

The variation of both ϕ and ρ are not too great to be attributed to the blurred signals. For the pyramid $(20\bar{2}1)$ observed by Brown at Frankford, Pa., the corresponding calculated angle is 77° 13′.

That is, the crystal consists of a predominant pyramid $(20\bar{2}1)$ with striated faces, and these striæ are due to an oscillation between this form and the prism*.

3. *Molybdenite from Cape Breton.*

Among a number of small crystals of molybdenite in the Egleston Museum labelled Cape Breton, one small crystal 4^{mm} broad by 1^{mm} thick showed five faces of a pyramid, two of which were unusually bright and intersected in a sharp edge. Placed with this edge vertical in the No. 2 Fuess goniometer, each face yielded a single vertically distorted image and permitted a rather close reading. The interfacial angle obtained was 58° 28½′, which corresponds to an angle with the cleavage of 77° 29′. The calculated angle for $(20\bar{2}1)$ is 77° 13′.

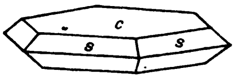
* The faces of such crystals are slightly curved and the crystals taper, preventing an exact application of a hand goniometer. It is probable that the angle cp=72° obtained by Hidden, (this Journal, xxxii, 210, 1886) on Renfrew molybdenite in this way is due to an oscillatory combination.

4. Molybdenite from Okanogan Co., Washington.

Messrs. Geo. L. English & Co. permitted me to examine over one hundred crystals from this locality. Many of these suggested a pyramid approximately the $(20\bar{2}5)$ found upon the crystal from the Enterprise Mine, but the crystals were bent and the faces bruised and rounded. Etch figures $\frac{1}{2}$ to 1^{mm} across and six-sided in cross section were observed and upon one crystal in which they were unusually distinct their parallelism to the hexagonal outline of the crystal was shown by the cross hairs of the microscope. This particular crystal also showed three systems of fine lines *parallel* to the edges of the cleavage in addition to a few coarse grooves perpendicular to these edges.

The best measurements were obtained from a crystal (fig. 3)

1



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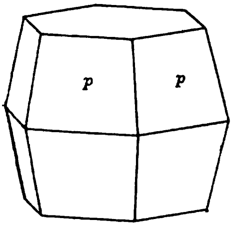

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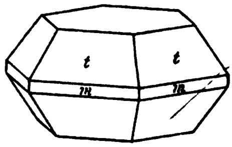

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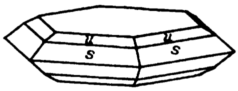


which distinctly showed two pyramids, the brighter being the flatter form but the steeper form being more developed. The crystal formed one of a group and only two zones could be adjusted for measurement. The images were multiple but the groups were small and the angles with the cleavage were:

Zone 1.	30° 17′	and	41° 46′
" 2.	29 32		Blurred
Average	29° 54′		41° 46

The nearest *simple* indices are $(10\bar{1}4)$ (28° 51′) and $(20\bar{2}5)$ 41° 23′. If 41° 46′ be taken as the angle of the unit pyramid, the pyramid $(10\bar{1}4)$ would have an angle of 29° 10′.

A crystal, bent like that figured by Knop so that the ridges divided the cleavage into three areas not in the same plane, yielded an angle of 76° 59′ between a pyramidal plane and the adjacent portion of the cleavage.

For $(20\bar{2}1)$ the angle 77° 13′ has been calculated.

5. Molybdenite from the Tilly Foster Iron Mine, Brewsters, N. Y.

Mr. F. V. Cruser presented the Egleston Museum with some specimens of molybdenite found by him at the mine. They occur in a cleavable calcite associated with small bright crys-

tals of green amphibole. On one crystal showing four faces of a pyramid two adjacent faces intersected in an edge which permitted careful adjustment on the Fuess goniometer. Each yielded a bright image of the signal which was only slightly distorted horizontally. The five readings of each face varied with respect to the mean, to the nearest half minute as follows:

First.	Second.
$-14\frac{1}{2}$	$+0\frac{1}{2}$
$+\ 4\frac{1}{2}$	$-6\frac{1}{2}$
$+\ 8\frac{1}{2}$	$-8\frac{1}{2}$
$+\ 6\frac{1}{2}$	$+6\frac{1}{2}$
$-\ 5\frac{1}{2}$	$+8\frac{1}{2}$

The angle obtained was 54° 08′, which corresponds to an angle with the cleavage of 65° 31′. The angle for $(10\bar{1}1)$ on the Frankford, Pa., crystals is 65° 35′.

6. *Molybdenite from Warren, N. H.*

In an old suite of molybdenite specimens in the Egleston Museum I found a number of small doubly terminated crystals three of which gave with the hand goniometer for all faces an angle with the cleavage between 54° and 55°. The pyramidal faces were striated and most of them curved and the cleavage was curved.

One crystal (fig. 4) showing twelve pyramidal planes was roughly oriented on the two-circle goniometer by the bent cleavage. Three faint signals were obtained with ϕ respectively 60°, 120° and 240°, which were approximately $\rho = 90°$. The crystal was then readjusted until these signals were accurately $\rho = 90°$.

The results were analogous to those obtained with the Aldfield crystal, that is images of the collimator signal were obtained for two different positions, each of which corresponded to a general illumination of the surface. In this case, however, both corresponded to oblique angles (pyramids). The results were

ϕ	ρ		ρ
0°	55° 15′	Two images	64° 36′
60	54 30	Bright image	64 58
119 06′	----		.
180 24	Blur		
240 20	54 25	Blurred image	64 18
Average	54° 43′		64° 27′

The simplest interpretation of these angles is that they correspond to $(20\bar{2}3)$ and $(10\bar{1}1)$, for which the corresponding calcu-

lated angles are 55° 45′ and 65° 35′. *Relatively* they are fairly close to calculated angles, for a unit angle of 64° 27′ would require for (20$\bar{2}$3) an angle of 54° 21′. It is not unreasonable to suppose an error in orientation or in the reading of the faint prismatic signals which would diminish both angles about the same amount.

The conclusion, therefore, is a dominant pyramid (20$\bar{2}$3) with striations due to an oscillation between this and (10$\bar{1}$1); the prism (10$\bar{1}$0) present as a slightly developed modification.

7. *The Knop and Hörnes Measurements.*

The crystals from Auerbach, Hesse, examined by Knop,* were parallel plates often with curved lamellæ. No regular twin striations but frequent wrinkling which appeared to be perpendicular to the sides of the hexagon producing approximations to rhombic thirds of faces. Measurements did not give any constant angles between these 'thirds,' which were evidently results of bending or wrinkling.

Although, as might be expected, these bent crystals gave no constant angles,† it is noteworthy that the averages both of the angles with the cleavage and the angles between adjacent faces closely approach those of the unit pyramid.

	Adjacent faces.	Faces with cleavage.
	50° 07′	71° 0′
	56 49	69 04
	56 37	57 20
Average	54° 31′	65° 48′

The Frankford, Pa., unit pyramid (10$\bar{1}$1) has angles respectively 54° 10′ and 65° 35′.

With respect to the crystals from Greenland, Hörnes states: "I have measured the crystals from Narksak and found the pyramid 123° 45′, 140° 57′."‡ Kenngott reëxamined§ the crystals and accepted the proof of their hexagonal form but pronounced the pyramid dubious, attributing it to the slipping of curved prisms and to tapering, but states, "one small crystal only showed a fairly distinct acute hexagonal pyramid."

Hintze‖ gives these angles as $pc = 70° \ 28\frac{1}{2}'$ and $pp = 56° \ 15'$. There appears to have been a slight error here, as for $pp = 56° \ 15'$, $pc = 70° \ 31\frac{1}{2}'$. This corresponds to (50$\bar{5}$4), for which the calculated angle is 70° 03′.

* Summarized from Neues Jahrb. f. Min., 1848, p. 43.
† Obtained by attaching mica to the faces.
‡ Uebersicht Darstell. des Mohsischen Min. Syst., 1847, p. 115.
§ Min. Forschungen, 1856, p. 104. ‖ Mineralogie, vol. i, p. 104.

Summary of Molybdenite Measurements.

Assuming the unit of Brown, viz., a pyramid *o* making an angle *co* with the cleavage equal 65° 35′ from which $\dot{c} = 1{\cdot}908$ is calculated, the observations may be summed up as follows: the angles with the cleavage being given.

Basal pinacoid, *c* (0001). Not observed except possibly on Enterprise, Ont. crystal.

Prism, *m* (10$\bar{1}$0). Frankford, Pa., sometimes prominent, Aldfield, Quebec, as part of striations; Warren, N. H., traces.

Pyramid, *q* (30$\bar{3}$1). Calculated angle 81° 24′.
Observed at Frankford, Pa. Measured angle 81° 31′.

Pyramid, *p* (20$\bar{2}$1). Calculated angle 77° 13′.

Measured angles		
	Frankford, Pa.	77° 15′
	Aldfield, Quebec	77 18
	Cape Breton	77 29
	Okanogan Co., Washington	76 59

Pyramid, *r* (50$\bar{5}$4). Calculated angle 70° 03′.
Observed at Narksak, Greenland. Measured angle 70° 31½′.

Pyramid, *o* (10$\bar{1}$0). Unit angle, Frankford, Pa., 65° 35′.

Measured angles		
	Tilly Foster Mine	65° 29′
	Auerbach, Hesse	65 48
	Warren, N. H.	64 27

Pyramid, *t* (20$\bar{2}$3). Calculated angle 55° 45′.
The Warren, N. H., angles for this, 54° 43′, and unit are *relatively* close for these indices but low for the Brown unit.

Pyramid, *s* (20$\bar{2}$5). Calculated angle 41° 23′.

Measured angles		
	Enterprise, Ontario	41° 26′
	Okanogan Co., Washington	41 46

Pyramid, *u* (10$\bar{1}$4). Calculated angle 28° 51′.
On Okanogan Co., Wash., the angle 29° 54′ was obtained, which was near these indices for 20$\bar{2}$5 = 41° 46′.

Columbia University, January, 1904.

ART. XXXIII.—*The Behavior of Typical Hydrous Chlorides when heated in Hydrogen Chloride;* by F. A. GOOCH and F. M. MCCLENAHAN.

(Contributions from the Kent Chemical Laboratory of Yale University—CXXVI.)

THE halogen salts of the metals are convertible by the action of water to oxy-salts, hydroxides, or oxides with varying degrees of readiness. In order that water may act hydrolytically upon barium chloride, for example, with liberation of hydrogen chloride and substitution of oxygen for chlorine, the temperature of the system must approach low redness, while magnesium chloride is attacked at a much lower temperature, and aluminum chloride is extremely sensitive to the metathetical action of water. These reactions follow the indications of the heat moduli of the transformations. To effect the metathesis between barium chloride and water, with formation of barium hydroxide and hydrogen chloride, a very considerable accession of energy from without the system is needed; the similar reaction between magnesium chloride and water requires less reinforcement from the outside; while the reaction between anhydrous aluminum chloride and water takes place easily. When a hydrous chloride is heated to the temperature of decomposition, the products will be the anhydrous chloride and water, or hydrogen chloride and an oxychloride, oxide or hydroxide, according to the nature of the particular chloride under experimentation. Hydrous barium chloride, $BaCl_2 \cdot 2H_2O$, parts with all its water and becomes anhydrous at 100° C.; the hydrous magnesium chloride, $MgCl_2 \cdot 6H_2O$ may lose a large part of its water at temperatures considerably above 100° without appreciable loss of chlorine, but exchanges chlorine for oxygen with formation of hydrogen chloride at higher temperatures; while hydrous aluminum chloride, $AlCl_3 \cdot 6H_2O$, loses water only with simultaneous formation of hydrogen chloride and exchange of chlorine for oxygen at 100°, and at temperatures at which all water is removed is converted to aluminium oxide.

It is obvious that in those cases in which hydrolytic decomposition takes place at temperatures below those at which the tendency to reversal ceases, the rate of decomposition must be affected by the concentrations of the active products of decomposition. So it is natural to expect that an increase in the concentration of hydrogen chloride in the system will serve to restrain hydrolytic action and decomposition of the chlorides at temperatures of incipient hydrolysis. Dumas* tried to take advantage of this principle in the preparation of anhydrous magnesium chloride, free from oxide, by prolonged drying of

* Ann. Chim. (3), lv, 137.

the hydrous chloride in an atmosphere of hydrogen chloride, but at the temperature of incipient redness at which Dumas worked the reversal of the hydrolytic effect is slow and difficult.

In the case of a hydrous chloride, like barium chloride, which shows no tendency to undergo hydrolytic decomposition at temperatures at which the water is completely removed, there seems to be no reason for anticipating any marked effect upon the progress of the dehydration when hydrogen chloride is made the surrounding atmosphere instead of air. With a hydrous chloride which evolves hydrogen chloride at the temperature of dehydration and forms an oxychloride, oxide or hydroxide the case is different. In such a case the effect of enormously increasing the concentration of hydrogen chloride in the system at the temperatures of incipient hydrolysis will naturally be to restrain the hydrolysis; but whether the result will be the formation of a chloride of lower content of water or an increased stability of the hydrous chloride for some range of temperature will turn upon the affinity of the anhydrous chloride for water.

In the process of dehydrating hydrous aluminum chloride, for example, an increase in the concentration of hydrogen chloride in the system will tend to retard the exchange of hydroxyl for chlorine at the temperature of incipient hydrolysis; but whether the result of such retardation will be the formation of the anhydrous chloride or simply an extension of the range of temperature for which the original hydrous chloride is stable is not immediately obvious, though the high degree of attraction existing between anhydrous aluminum chloride and water, as indicated in the large heat of hydration of that salt, would seem to suggest the latter alternative.

In the work of which an account follows the effect of substituting an atmosphere of hydrogen chloride for ordinary air in experiments upon the dehydration of typical hydrous chlorides was studied. Barium chloride as the representative of salts which lose water without other decomposition, magnesium chloride which suffers some loss of chlorine when fully dehydrated, and aluminum chloride which loses all its chlorine when similarly dehydrated, were the hydrous chlorides taken for these experiments.

In these experiments two combustion tubes of large size set horizontally side by side in a tubulated paraffine bath served as heating chambers. Each tube was fitted with a thermometer and connected through a drying bulb and column with an aspirator. Portions of the hydrous chloride to be treated were weighed into porcelain boats. One of these boats was inserted in each tube about midway in the bath (heated to a regulated temperature) and immediately below the bulb of the thermom-

eter, so that the temperature of the material in the boat might be indicated by the thermometer as nearly as possible. Through one tube was drawn slowly a current of air purified by caustic potash and sulphuric acid, and through the other was sent a slow current of hydrogen chloride, generated in a Kipp generator by the action of sulphuric acid upon sublimed ammonium chloride in lumps. At the expiration of a definite period, the boat was withdrawn, placed in a desiccator and weighed after a suitable interval for cooling. The residue in the boat was dissolved in water, acidulated with nitric acid and the chlorine in it was precipitated by silver nitrate, the silver chloride being weighed on asbestos. Thus it was possible to determine directly the loss of water and chlorine from individual portions of the salt under experimentation during definite intervals and at fixed temperatures, both in an atmosphere of hydrogen chloride and in air, and to find for each individual portion under experiment what proportion of the total loss was hydrogen chloride and what was water. The tabular statements and the diagrams show the course of decomposition of the various salts for the temperatures indicated.

Hydrous Barium Chloride.

For the experiments with barium chloride a well-crystallized specimen showing by analysis a normal content of chlorine was taken. During the process of dehydration at temperatures ranging as high as 100°, at which point all water was expelled, there is no evidence of loss of chlorine, and the course of dehydration, as would be anticipated, appears to be wholly uninfluenced by the presence of hydrogen chloride.

The slight increase in the chlorine generally found in the salt after exposure to the atmosphere of hydrogen chloride may be properly attributed to occlusion or adsorption of hydrogen chloride. The data of individual experiments are gathered in Table I, p. 368, and the general course of action is followed in the diagram.

Hydrous Magnesium Chloride.

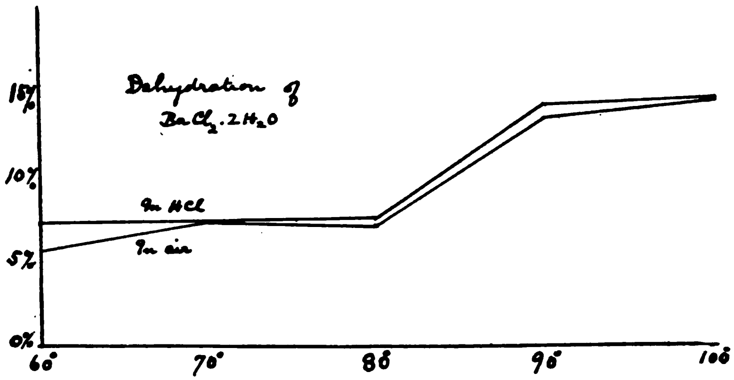
Similar experiments, the data of which are given in Table II, were made with hydrous magnesium chloride dried *in vacuo* over sulphuric acid and of nearly ideal constitution.

So far as these results go, it appears that the loss of chlorine during the process of dehydration of the hydrous magnesium chloride, $MgCl_2 \cdot 6H_2O$, is generally small until a temperature approximating 200° is reached; that at temperatures between 100° and 130° hydrogen chloride generally restrains dehydration, while above that temperature dehydration progresses more

TABLE I.

Ba	56·24
Cl_2	29·02
$2H_2O$	14·74
	100·00

	Atmosphere.	Weights taken. grm.	Loss on heating.		Chlorine in residue.			Water evolved. Per cent.	Time. hrs.	Temperature.
			grm.	Per cent.	grm.	Per cent.	Variation from theory.			
1	Air	0·3335	0·0189	5·67	0·0969	29·06	+0·04	5·67	½	60°
	HCl	0·2952	0·0205	6·94	0·0866	29·34	+0·32	7·27	½	
2	Air	0·3609	0·0262	7·26	0·1045	28·96	—0·06	7·20	½	70°
	HCl	0·3004	0·0213	7·09	0·0875	29·13	+0·11	7·21	½	
3	Air	0·2919	0·0206	7·06	0·0848	29·05	+0·03	7·09	½	80°
	HCl	0·3362	0·0243	7·23	0·0981	29·18	+0·16	7·39	½	
4	Air	0·4161	0·0557	13·38	0·1207	29·01	—0·01	13·37	½	90°
	HCl	0·2972	0·0389	13·09	0·0894	30·08	+1·06	14·18	½	
5	Air	0·4904	0·0711	14·49	0·1423	29·02	0·00	14·50	½	100°
	HCl	0·4272	0·0630	14·75	0·1236	28·93	—0·09	14·64	½	



rapidly in the presence of hydrogen chloride. Hydrogen chloride appears to influence in no very marked and regular way the loss of the first third of the water.

TABLE II.

Mg	11·98
Cl_2	34·87
$6H_2O$	53·15
	100·00

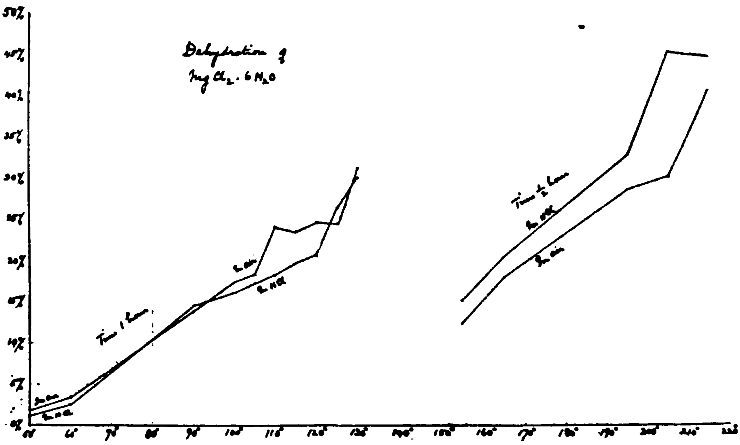
Atmosphere.		Weight taken. grm.	Loss on heating. grm.	Loss on heating. Per cent.	Chlorine in residue. grm.	Chlorine in residue. Per cent.	Chlorine in residue. Variation from theory.	Water evolved. Per cent.	Time. hrs.	Temperature. C°.
1	Air	0·5004	0·0093	1·85	----	----	----	1·85	1	50
	HCl	0·4330	0·0046	1·06				1·06		
2	Air	0·5139	0·0181	3·52	0·1781	34·66	− ·21	3·31	1	60
	HCl	0·4310	0·0110	2·55	0·1503	34·87	·00	2·55		
3	Air	0·7281	0·0387	5·31	----	----	----	----	1	70
	HCl	0·6093	0·0240	3·93						
4	Air	0·7193	0·1026	14·26	0·2483	34·52	− ·35	13·90	1	90
	HCl	0·6183	0·0900	14·55	0·2155	34·85	− ·02	14·51		
5	Air	0·2854	0·0497	17·41	0·9913	34·79	− ·08	17·33	1	100
	HCl	0·2453	0·0405	16·51	0·8486	34·60	− ·27	16·23		
6	Air	0·5036	0·0927	18·41	0·1755	34·85	− ·02	18·39	1	105
	HCl	0·4591	0·0799	17·40	0·1599	34·83	− ·04	17·36		
7	Air	0·6679	0·1611	24·12	0·2327	34·84	− ·03	24·09	1	110
	HCl	0·5012	0·0908	18·11	0·1750	34·91	+ ·04	18·15		
8	Air	0·5893	0·1404	23·82	0·2055	34·87	·00	23·82	1	115
	HCl	0·5145	0·1018	19·78	0·1801	35·00	+ ·13	19·91		
9	Air	0·5012	0·1314	26·21	0·1678	33·48	−1·39	24·78	1	120
	HCl	0·4542	0·0944	20·78	0·1586	34·92	+ ·05	20·83		
10	Air	0·4249	0·1043	24·55	0·1480	34·85	− ·02	24·53	1	125
	HCl	0·4176	0·1104	26·44	0·1461	34·99	+ ·12	26·56		
11	Air	0·4891	0·1511	30·89	0·1721	35·19	+ ·32	31·21	1	130
	HCl	0·3662	0·1093	29·85	0·1283	35·04	+ ·17	30·02		
12	Air	0·3583	0·0452	12·61	0·1240	34·61	− ·16	12·45	½	155
	HCl	0·3300	0·0503	15·24	0·1151	34·88	+ ·01	15·25		
13	Air	0·3918	0·0716	18·27	0·1359	34·69	− ·18	18·09	½	165
	HCl	0·3964	0·0811	20·46	0·1376	34·71	− ·16	20·30		
14	Air	0·3618	0·1057	29·21	0·1240	34·27	− ·60	28·59	½	195
	HCl	0·3695	0·1225	33·15	0·1278	34·59	− ·28	32·86		
15	Air	0·3330	0·1079	32·40	0·1091	32·76	−2·11	30·13	½	205
	HCl	0·3209	0·1426	44·44	0·1143	35·62	+ ·75	45·21		
16	Air	0·2728	0·1156	42·38	0·0906	33·20	−1·67	40·66	½	215
	HCl	0·3583	0·1671	46·64	0·1179	32·90	−1·97	44·61		

Hydrous Aluminum Chloride.

Pure hydrous aluminum chloride, $AlCl_3 \cdot 6H_2O$, was made by dissolving the C. P. hydrous chloride of the laboratory in the least possible amount of aqueous hydrochloric acid, filtering the solution through asbestos, and saturating the clear solution with gaseous hydrogen chloride. The crystallized chloride thus obtained was collected on asbestos in a perforated cone,

washed with concentrated hydrochloric acid, sucked as dry as possible by the pump, and exposed seventy-two hours in a desiccator containing quicklime, to absorb free hydrogen chloride, as well as sulphuric acid to take up water. The composition of the product was fixed by determining the aluminum as the oxide by ignition with mercuric oxide,* and the chlorine by precipitation with silver nitrate, as shown in the following analyses:

	Analysis I.	Analysis II.	Theory for $AlCl_3 \cdot 6H_2O$.
Aluminum	11·17	11·21	11·20
Chlorine	43·92	44·18	44·05
Water (by difference)	44·91	44·61	44·75
	100·00	100·00	100·00



Weighed portions of this preparation lost practically nothing in three weeks at the ordinary temperature over sulphuric acid, calcium chloride, and phosphorous pentoxide, and remained almost unchanged when heated to 98°.

The details of two parallel series of experiments in which portions of the hydrous aluminum chloride were heated in air or in a current of hydrogen chloride are recorded in Table III, and the course of the change in weight and loss of chlorine at various temperatures in air and in hydrogen chloride are shown in the diagram.

From the results of these experiments it appears that the inhibitive action of the atmosphere of hydrogen chloride upon the dehydration of hydrous aluminum chloride is marked at the lower temperatures. While the hydrous salt when heated in

* Gooch and Havens: This Jour. vi, 45 (1898).

TABLE III.

Al	11·20	per cent
Cl_3	44·05	"
$6H_2O$	44·75	"
	100·00	

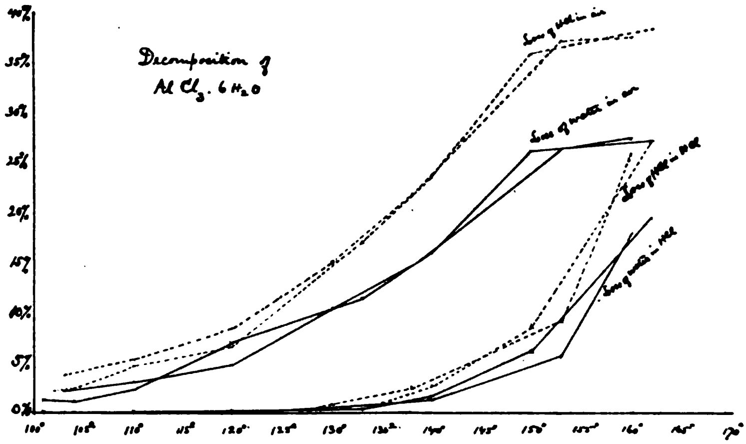
Series I.

Atmosphere.	Weight taken. grm.	Loss on heating. grm.	Loss on heating. Per cent.	Chlorine in residue. grm.	Chlorine in residue. Per cent.	HCl lost. Per cent.	Water lost. Per cent.	Time. hrs.	Temperature. C°.
Air	0·3745	0·0123	3·28	0·1571	41·96	2·15	1·13	1	101
HCl	0·4419	0·0006	·13	----	----	----	----		
Air	0·4314	0·0145	3·36	0·1801	41·75	2·36	1·00	1	104
HCl	0·3725	0·0006	·16	----	----	----	----		
Air	0·3719	0·0261	7·02	0·1467	39·44	4·74	2·28	1	110
HCl	0·4413	0·0008	·18	----	----	----	----		
Air	0·3225	0·0446	13·83	0·1206	37·39	6·84	6·97	1	120
HCl	0·3141	0·0010	·32	----	----	----	----		
Air	0·3725	0·1064	28·56	0·1022	27·43	17·08	11·48	1	133
HCl	0·4583	0·0020	·43	----	----	----	----		
Air	0·5664	0·2254	39·80	0·1182	20·87	23·82	15·98	1	140
HCl	0·4503	0·0207	4·60	0·1860	41·30	2·83	1·77		
Air	0·3503	0·2185	62·38	0·0318	9·08	35·99	26·39	1	150
HCl	0·2563	0·0382	14·90	0·0911	35·54	8·75	6·15		
Air	0·3085	0·2033	65·89	0·0202	6·55	38·56	27·33	1	162
HCl	0·5230	0·2441	46·67	0·0930	17·78	27·01	19·66		

Series II.

Atmosphere.	Weight taken. grm.	Loss on heating. grm.	Loss on heating. Per cent.	Chlorine in residue. grm.	Chlorine in residue. Per cent.	HCl lost. Per cent.	Water lost. Per cent.	Time. hrs.	Temperature. C°.
Air	0·2292	0·0135	5·89	0·0926	40·40	3·75	2·14	1	103
HCl	0·2425	0·0000	----	----	----	----	----		
Air	0·2855	0·0234	8·20	0·1113	38·97	5·21	2·99	1	110
HCl	0·3139	0·0002	·06	----	----	----	----		
Air	0·3640	0·0482	13·24	0·1307	35·97	8·37	4·87	1	120
HCl	0·2860	0·0005	----	----	----	----	----		
Air	0·2346	0·0596	25·40	0·0687	29·36	15·10	10·30	1	130
HCl	0·2437	0·0022	·90	----	----	----	----		
Air	0·4178	0·1543	36·93	0·0944	22·59	22·04	14·89	1	138
HCl	0·2984	0·0117	3·92	0·1241	41·59	2·53	1·39		
Air	0·3375	0·2159	63·97	0·0260	7·70	37·37	26·60	1	153
HCl	0·3583	0·0539	15·04	0·1258	35·11	9·19	5·85		
Air	0·2425	0·1607	66·27	0·0154	6·35	38·75	27·52	1	160
HCl	0·2512	0·1105	43·99	0·0472	18·79	25·97	18·02		

air loses water appreciably at 101°, the loss in an atmosphere of hydrogen chloride is not considerable until the temperature rises to about 130.° In both cases, however, loss of weight is accompanied by hydrolytic action. At the outset, for every gram-molecule of water liberated approximately a gram-molecule of hydrogen chloride is eliminated: later the proportion of water to the hydrogen chloride increases, because, no doubt, the aluminum hydroxide first formed begins to lose water.



Discussion of Results.

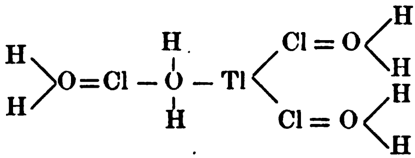
It appears that hydrogen chloride is without influence of any kind in the dehydration of hydrous barium chloride, $BaCl_2\cdot 2H_2O$, at temperatures not exceeding 100°, at which the process is complete.

In dehydrating hydrous magnesium chloride, $MgCl_2\cdot 6H_2O$, hydrogen chloride appears to have little or no effect upon the loss of the first third of the water (which may be removed at 100°), to act in restraint of the process of dehydration when the salt is placed at once in an atmosphere heated to a point between 100° and 130°, and to aid dehydration at temperatures above 130°. The hydrolytic dissociation of the salt is not very marked in either air or hydrogen chloride until the temperature approaches 200°.

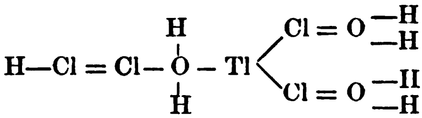
The dehydration of aluminum chloride, $AlCl_3\cdot 6H_2O$, is inhibited by an atmosphere of hydrogen chloride until a temperature of about 130° is reached. Above that point, as in air above 100°, water and hydrogen chloride are evolved simultaneously.

In attempting to account for the relation of water of crystallization to the general molecular configuration of hydrous

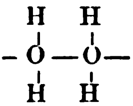
chlorides, Cushman* has proposed to make use of the hypothesis of quadrivalent oxygen in a way to show linkings of stronger and weaker combination. Those molecules of water which are held more firmly than others are placed within the molecular complex, while those molecules of water which admit of easy removal without affecting the constitution of the anhydrous salt are attached externally. According to Cushman, the hydrous thallic chloride may be represented by the symbol



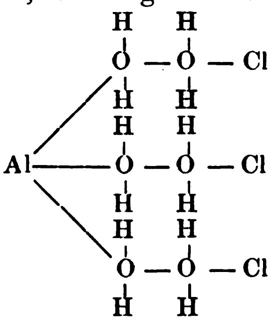
which by placing a single molecule of water within the complex brings to view the observed fact that at the ordinary atmospheric temperatures one molecule of water is held more firmly than the other three. The easy transformation of this salt by the action of hydrochloric acid, as observed by Meyer,† is exhibited by a comparison of the symbol with that of the chlorthallic acid derived from it.



For the molecule of hydrous aluminum chloride Cushman makes the suggestion that the water is held in three linkages



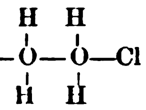
within the complex, according to which the symbol would be



* Am. Chem. Jour., xxvi, 505. † Loc. cit.

This symbol brings out the experimental fact that water cannot be eliminated without simultaneous liberation of hydrogen chloride, at least in the first reaction, and shows that from a molecule thus constituted the formation of aluminum hydroxide or oxide with evolution of water and hydrogen chloride would seem to be natural.

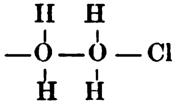
A little consideration makes it obvious, however, that the decomposition of a molecule containing the group



need not in every case result finally in the elimination of all chlorine as hydrochloric acid and the formation of the metallic hydroxide, oxyhydroxide, or oxide. When conditions favor, there would seem to be nothing to prevent more or less secondary reaction of the liberated hydrogen chloride upon the metallic hydroxide first produced. Whether such secondary reaction will take place in any given case will depend largely upon the relative strengths of affinities of which we have, at least in many cases, some sort of measure in the heats of reaction.

It is not likely, for example, that the reaction of hydrogen chloride upon aluminum oxide with formation of aluminum chloride and gaseous water will take place to any considerable degree when the heat of such reaction would be negative to the extent of approximately 27,000 cal. for every gram-molecule of aluminum oxide converted. On the other hand, it is not unreasonable to look for some convertion of magnesium oxide to magnesium chloride by a reaction which involves the liberation of approximately 19,000 calories to the gram-molecule of magnesium oxide attacked. So it appears that an inner linkage such as is suggested by Cushman might possibly exist in the case of such a salt as hydrous magnesium chloride without coming very much into evidence by reason of the evolution of hydrogen chloride and formation of magnesium hydroxide or oxide when the salt is heated.

Turning now to the consideration of what is likely to occur when a molecule possessing the linking

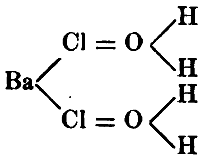


is heated in presence of hydrogen chloride, it is obvious that the first effect of increasing the concentration of hydrogen

chloride at the temperature of incipient decomposition would be to reverse the action of decomposition and to hold the hydrous salt in a condition of greater stability. In the case of a salt which when heated evolves all its chlorine this inhibitive action would be the only effect observed. In the case of salts which give in the decomposition hydroxides or oxides capable of reacting with hydrogen chloride under the conditions with the formation of an anhydrous chloride, the effect of heating in an atmosphere of hydrogen chloride might also be increased stability for a certain range of temperature, but this limit of stability once passed, a second effect of the hydrogen chloride tending to increase the rapidity of the formation of the anhydrous chloride and so to produce a more rapid evolution of water from the salt as compared with the amount of water set free from the salt heated *per se* at the same temperature might become prominent. It is to be expected that one and the same salt might exhibit each of these effects, the one restraining dehydration and the other aiding it, at appropriate temperatures.

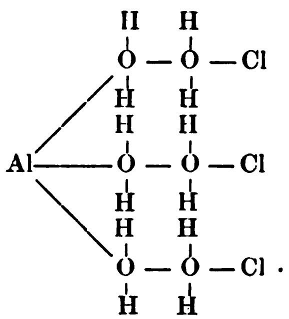
Now, returning to the salts under investigation, we find that the experimental results fall very well into line with the assignment of symbols according to Cushman's hypothesis.

The symbol



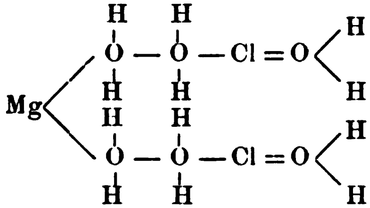
suggests the observed easy detachment of water and the absence of all effect of decomposition of the chloride when the water is removed at 100°, and suggests no reason why any special effect should be anticipated when hydrogen chloride is made the medium in which dehydration takes place.

The symbol



indicates the experimental fact that water cannot be removed from the salt without simultaneous breaking out of hydrogen chloride at least in the primary action, and suggests that increase in the concentration of hydrogen chloride in the system should retard the dehydration of the salt, as was observed.

The symbol



shows that one-third of the water in the salt should be evolved easily and without hydrolytic effect. Thereafter, the atmosphere of hydrogen chloride will act to increase the stability of the chloride now containing four molecules of water within the complex and so to limit the rate of dehydration as compared with that in air for some range of temperature, as was observed between 100° and 130°. The limit of increased stability once passed, the rate of dehydration will depend upon the predominance of the primary effect of decomposition with liberation of water and hydrogen chloride or of the secondary action of hydrogen chloride upon the residual oxide or hydroxide. In case the secondary effect predominates, the rate of dehydration will be greater in the atmosphere of hydrogen chloride, as it was in six out of seven experiments at temperatures between 120 and 215°.

So it appears, that the phenomena of dehydration of the hydrous chlorides under discussion, in the atmosphere of hydrogen chloride as well as when heated *per se*, find reasonable expression upon the hypothesis of varying relations of position of the water within the molecular complex, as suggested by Cushman upon the assumption of quadrivalent oxygen. The behaviour of hydrous chlorides in an atmosphere of hydrogen chloride should in many cases afford means of differentiating the water within the complex from water attached externally.

ART. XXXIV.—*On Stegomus Longipes, a New Reptile from the Triassic Sandstones of the Connecticut Valley;* by B. K. EMERSON and F. B. LOOMIS. (With Plate XXII.)

IN spite of the great abundance of tracks preserved in the Triassic sandstones of the Connecticut valley indicating a rich land fauna, the number of osseous remains is limited to three dinosaur specimens and a portion of an Aëtosaurus-like carapace, called by Marsh, Stegomus*. On account of this rarity, the appearance of a new fossil throwing light on the land fauna, and on the makers of the well known tracks, is of general interest.

Some seven years ago, while removing the superficial layers of sandstone in the Hines Quarry, which is about a mile east of the village of East Longmeadow, Mass., Mr. G. B. Robinson found the small lizard-like specimen which is the subject of this paper. It occurred in a dense layer of red sandstone some ten feet below the surface and immediately above the thicker and softer layers which are used commercially for building stone. The discoverer removed the blocks containing the animal to his door yard, where they remained for about seven years exposed to the weather. They were seen by Mr. and Mrs. E. D. White, who obtained possession of them and brought the fossil to Springfield. Mr. and Mrs. White kindly placed this finely preserved fossil at our disposal for study and description.

The specimen consists of three pieces containing the major part of the whole animal. All but a thin interrupted film of the bone has been leached out, leaving spaces which are filled with calcite. It is, then, largely a cast, both the upper and lower surfaces of the bone being impressed on one block or the other. The first block contains most of the fossil, the splitting having exposed the under surface of the bones roofing the head, of the carapace from the head to the pelvis (28 pairs of plates), the bones of the right arm and left foot. The second block contains the impression of the upper surface of the same parts. The third is a chip, flaked off just in front of the pelvis and exposing the vertebræ of that region.

Skull.—This is broadly triangular in outline, tapering to a pointed snout. The upper surface of the cranium seems to have been completely roofed with bone, except possibly directly over the orbit. Two supraorbital bones are distinctly indicated, but between them and the frontals is a space which seems to have been open (see ? in fig. 2, Pl. XXII). Sutures are present

* Marsh, O. C., 1896, this Journal (4), ii, pp. 59–62.

showing that the dermal bones were paired along the middle line. The premaxillæ are short, the nasals are rather long, but the boundaries of the other bones cannot be made out. A vertical break shows the side of the skull imperfectly, as restored in fig. 3, Pl. XXII. The parts actually present are indicated by the complete line, while restoration is indicated by a broken line. It is a low skull, being about one-third as deep as long. The quadratum is well back, making a long jugal arch. An antorbital vacuity is present though its boundaries are very imperfectly indicated. The orbit is moderately large, being distinctly bounded off from the temporal vacuities as indicated. It has above it at least two supraorbital bones. That there is a large lateral temporal vacuity is certain. A forward projection of bone in the squamosal region seems to indicate a dividing arcade between this and a supra-temporal vacuity, but the arcade is not complete and is not therefore certain. On the maxilla of the left side one tooth and a part of a second is preserved, showing them to be tiny conical affairs. The depth of the lower jaw is about 3^{mm}, being a light slender mandible.

Carapace.—The dorsal side of the body was protected by a double row of plates, on either side. Those along the middle line are wide, their outer edges being flanked with small quadrate scutes. From the head to the pelvis there are 28 sets of plates, which are narrow and inflexed in the neck region, widen till the middle of the body is reached, and then gradually taper toward the tail. The arrangement and relations of these scutes are seen in fig. 2. Each plate of the median row is usually about 4–4 $1{\cdot}2^{mm}$ from front to back. The third and fourth, however, are about half as wide as the rest, while the fifth is much the widest, being wider than the two preceding taken together. Possibly some of this variation is due to the curvature of the neck, but most of it is clearly the bone itself. The rear margin of each scute overlapped the front of the succeeding one, as is clear in the cast of the upper surface. Marsh considered that in his specimen this was not the case, but the fossil shows only the under surface of the scutes and they appear exactly as do those in the specimen under description. Marsh used this character to distinguish Stegomus from Aëtosaurus, but the contrasts must be found in other characters, as is shown later. Along the outer margins of plates 5–9 small quadrate scutes were brought into sight by preparation. The nature of the fossil does not permit further preparation, but doubtless similar scutes occur all along the side of the body. On the cast of the upper surface of the scutes, there are indications that the surface was pitted but the coarseness of the sandstone prevents certainty.

Vertebræ.—Three presacrals are exposed, each deeply bicon-

cave and with long transverse processes. Two vertebræ only are involved in the sacrum, their moderately long transverse processes supporting the ilium. How completely they are united is not clear on account of the broken condition of the vertebræ, but they appear slightly separated. Three and a half deeply biconcave caudals are all that are preserved. The transverse processes of these are even longer than on the pre-sacrals and quadrate in section. From the sacrum back they are progressively longer, suggesting a broad flat tail such as is known for Aëtosaurus.

Fore Limb.—Of the pectoral girdle only the scapula is present, and this is a broad triangular bone 9^{mm} long by 5^{mm} deep. Its upper margin lies parallel to small lateral plates 7–9 in the series. The leg is unusually long, the slender humerus being $1\frac{1}{2}^{mm}$ in diameter and 24^{mm} in length, a bone nearly straight and swelling slightly at either end. The radius and ulna are but $\frac{3}{4}^{mm}$ in diameter and 19^{mm} long. As the specimen lies, the radius crosses the ulna, but whether this indicates great flexibility or is mere chance is not to be determined. The fore foot is lacking.

Hind Limb.—An ilium 12^{mm} long, the front and rear ends of which curve strongly outward, is present, but only its rough outline is to be made out. Of the limb bones only short fragments are discernible, where they are broken across; but enough is visible to show the direction and diameter of the bones, and by extending these the length can be approximately found. This indicates a leg slightly longer than the fore leg. The femur was $1\frac{1}{2}^{mm}$ in diameter and 26^{mm} in length (by reconstruction). The tibia and fibula are each about the same size, $\frac{3}{4}^{mm}$ in diameter and 21^{mm} long (by reconstruction). The left foot is well preserved. The individual tarsals are not to be made out. Four toes are well preserved, but a fifth is nowhere even indicated. The length of the toes on the figure is probably a little short, as each seems incomplete at the end. The metapodials are long, but the details of the toes do not come out with certainty, though a slight widening at intervals was taken to indicate the joints, and they are drawn on that supposition.

Comparison.—This animal resembles most closely Marsh's *Stegomus arcuatus*, of which twenty dorsal sets of plates are described. It is a much smaller species and presents most of the important features, thus allowing a conception of the animal and its relationships. *Stegomus longipes* is about one-third the size of the preceding species, which is the only comparison readily made, as Marsh's fossil is so incomplete. It belongs to the Aëtosauridæ* and resembles that genus in many important features, but there are enough characters of weight to demand a separate genus, as established by Marsh. Ornitho-

* Fraas O. 1877, Württemb. naturw. Jahreshefte, xxxiii, Festschrift.

suchus and Erpetosaurus of Newton* also have some features resembling *S. longipes* but are far wider differentiated than the German genus. Aëtosaurus has about twenty-five sets of plates from the head to the pelvis, each consisting of a median pair of large scutes and small quadrate scutes outside these. Stegomus has about twenty-eight exactly similar sets of plates.

In the skull, however, there are marked contrasts. The orbit of both genera is bounded above by extra supraorbital bones, but the orbit of the Aëtosaurus is further back than that of Stegomus: the result of which is that the former has only a single small supra-temporal vacuity, while the latter has at least a very large vacuity, and possibly that divided into a supra-temporal and a lateral temporal vacuity. The Stegomus has a wider skull and above the orbit a vacuity or at least a deep depression. The vertebræ of Aëtosaurus are procœlous, while those of Stegomus are amphicœlous. Ornithosuchus has platycœlous vertebral centra. The sacrum in the other known Aëtosauridæ includes three vertebræ, but in Stegomus only two are united to the ilium. Both the fore and hind limbs of Stegomus are much longer and more slender than the Aëtosaurus, this being the character which has suggested the specific name longipes.

The features above described show this fossil to be the remains of a small armoured lizard-like creature, with long legs. It seems to be a land form and of extreme agility.

The following are the measurements of the principal parts:

Length from snout to root of tail	149^{mm}
Length of skull	35
Breadth of skull in occipital region	27
(29 allowing for fracture)	
Depth of skull in quadrate region	11

Median Plate 2...	8^{mm}	transversely	by	$4\frac{1}{2}$	longitudinally
" Plate 3...	$5\frac{1}{2}$	"	"	2	"
" Plate 4...	5	"	"	$2\frac{1}{2}$	"
" Plate 5...	$4\frac{1}{2}$	"	"	5	"

The succeeding plates gradually increase transversely up to 10^{mm} at about the middle of the body and then slowly diminish again. All are drawn to scale in figure 2, Pl. XXII.

The vertebral centra in front of the pelvis are $3\frac{1}{2}^{mm}$ long by 3^{mm} wide. Caudal vertebræ 3^{mm} long by 2^{mm} wide. The transverse process of the last vertebræ are 6^{mm} long.

EXPLANATION OF PLATE XXII.

FIGURE 1.—*Stegomus Longipes*, photograph natural size.
FIGURE 2.—*Stegomus Longipes*, outline drawing to show details, dotted lines indicating the portions reconstructed.
FIGURE 3.—*Stegomus Longipes*, side view of skull reconstructed.

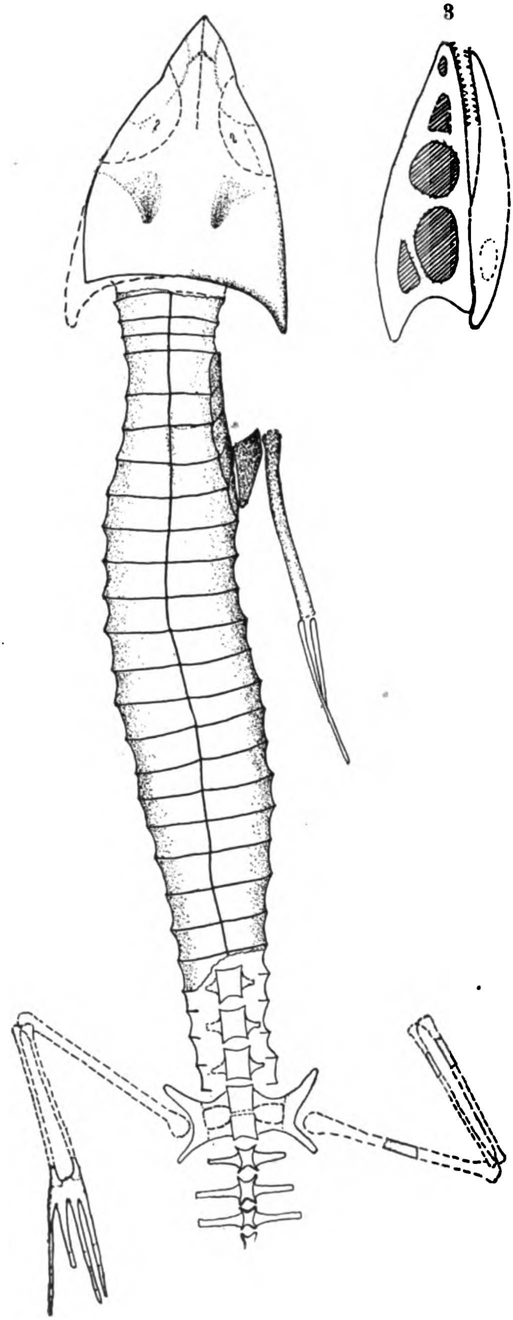
Amherst College, Mar. 1, 1904.

* Newton E. T. 1894, Phil. Trans., vol. clxxxv, Reptiles of Elgin Sandstones.

1

2

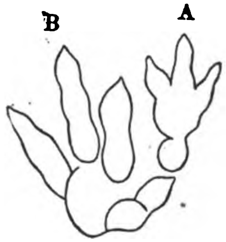
3



ART. XXXV.—*Note on the probable Footprints of Stegomus Longipes;* by R. S. LULL.

THE discovery of a nearly complete specimen of Stegomus in the Triassic sandstones of the Connecticut Valley proves a great boon to the student of footprints, for it at once affords a clue to the interpretation of a most remarkable series of quadrupedal tracks which are included under the ichnite genus Batrachopus (Anisopus) of Hitchcock.

Briefly characterized, these tracks were made by a series of forms truly quadrupedal in gait, with a tetradactyl pes and a pentedactyl manus, the latter being considerably smaller and rarely showing the impression of all of the digits; sometimes four, generally but three leaving their imprints. The phalangeal pads are generally distinct and betray a formula which at once places the group among the diaptosaurian reptiles, while the acuminate claws seem to imply a carnivorous mode of life.



Footprints of *Batrachopus gracilis* E. Hitchcock, Natural size. A manus, B pes.

In one feature this genus separates itself sharply from most Reptilia, and that is in the extremely long stride in proportion to the length of the pes, the ratio of foot to step being on the average as one to six; this together with a very narrow trackway, shown by the footprints being nearly in a right line, would indicate a creature with long stilted limbs and a gait like that of a cursorial mammal. Edward Hitchcock (Ichnology of Massachusetts, Boston, 1858, pp. 62, 63) recognized the saurian nature of the group, but could not reconcile the limb proportions with those of any known reptile, hence he reasoned that they might have been mammiferous. The inequality of the fore and hind feet together with the remote age of the impressions suggested to him the marsupials, and he says finally that: "although the marsupial type must have predominated the . . . . crocodilian characters . . . . ought not to be overlooked, and therefore I call the animal a *Loricoid Marsupialoid*."

Lull, in his recent memoir (Mem. Boston Soc. Nat. Hist, vol. 5, No. 11, p. 482), thought that Batrachopus might represent a survivor of the ancient dinosaurian stem from the very dinosauroid pes, which, though tetradactyl, with all of the digits pointing forward, is of such a character that the typical dinosaurian foot could readily have been derived from it The long-limbed Kadaliosaurus strongly suggested the genus under con-

sideration, which was therefore provisionally placed in the order Protorosauria of Seeley. A comparison was made however between Batrachopus and Aëtiosaurus, but those forms described by Fraas lacked the proportions necessary to correlate the two genera.

In the Aëtiosaur (*Stegomus longipes*), described by Emerson and Loomis on p. 377 of this number, we find a form whose stilted limbs and comparatively narrow body give it just the proportions one would suppose Batrachopus to have, and a careful comparison with the wealth of material contained in the Hitchcock ichnological cabinet of Amherst College seems to correlate it beyond doubt with the species *Batrachopus gracilis* E. Hitchcock, for the correspondence in size is exact.

The genus Batrachopus contains three typical species, *B. deweyanus* E. H., the type species, *B. dispar* Lull, and *B. gracilis* E. H. the last presenting at least two varieties differing from each other mainly in size, each being in this respect comparatively constant, though gradational specimens do occur. Of these varieties the type specimen, the one here figured, that described by Hitchcock,* is of the smaller phase, and it is with this that *Stegomus longipes* agrees, while the larger form is that described and figured in the author's memoir (loc. cit., p. 484, fig. 3). These two forms are mainly from two localities: the typical variety being seen most commonly on a ripple-marked gray shale from the Horse Race near Gill, Massachusetts, the slabs being covered with tracks running in every direction as though the creatures were gregarious in habits, as the specimen of Aëtiosaurus described by Fraas† would also seem to indicate.

The larger variety has its typical locality at the Lily Pond quarry at Turners Falls, Massachusetts, which has yielded so many of Hitchcock's types, and the specimens are for the most part beautifully preserved impressions on a dark red shale, which preserves detail with wonderful fidelity.

Geographically *Batrachopus gracilis* ranges from Massachusetts through Connecticut, New Jersey and Pennsylvania, and hence it is sufficiently numerous and widespread to be among the species most likely to be preserved as fossils.

If one may judge from relative size, it is possible that the footprints of *Stegomus arcuatus* Marsh‡ are those to which the name *Bratrachopus dispar* Lull has been given.

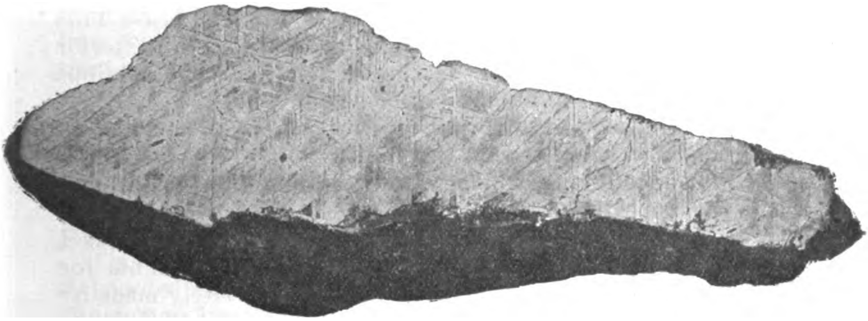
It would seem therefore that the correct placing of Batrachopus would be not among the Protorosauria but in the suborder Aëtiosauria of the order Parasuchia of Huxley.

* Mem. Amer. Acad. Arts and Sci. (2), iii, p. 228, pl. 16, fig. 3, 4.
† Württem. naturwiss. Jahres., xxxiii, 1877.
‡ This Journal (4), ii, p. 59, pl. i.

ART. XXXVI.—*The Canyon City Meteorite from Trinity County, California*; by HENRY A. WARD.

ON page 469 of vol. xxix (1885) of this Journal, Prof. Charles Upham Shepard called attention to a mass of meteoric iron purporting to come from Canyon City, Trinity County, California, whence it had been brought by Captain C. W. Davis of Holmes Hole, Mass., some ten years previous.

Through the kind aid of Mr. A. P. Crowell of Wood's Holl, I was able to find Captain Davis and to obtain the specimen, which the latter gentleman had had in his possession for more than a quarter of a century. Captain Davis' recollections of the finding of the mass were clear, yet with little detail. It was found in the summer of 1875 on the border of a little stream which flows into the Trinity River, and about three



Section of Canyon City Siderite, ½.

miles northeast from the town of Canyon City. It was brought to Captain Davis by John Driver, who discovered it on the surface of the ground. Captain Davis retained it entire during his stay of several years in Canyon City, and subsequently brought it with him to his Massachusetts home, where he had since kept it carefully wrapped in a napkin and had shown it to few visitors.

The form of the specimen was nearly a square, about 8½ by 7½ inches in length and breadth, and 2½ inches in average thickness. One surface was slightly convex, the other slightly concave. The whole surface was much oxidized, and the flaking off of scales of the decomposed iron had entirely obliterated any traces of "pittings" which it originally doubtless had over its surface. The general color of the whole is a dark yellowish brown. The weight before cutting was 18¾ lbs. We have cut several slices from the mass.

The etched sections show a strongly marked octahedral structure with large figures; the plates of kamacite vary much in

size, ranging generally from 1 to 2^{mm} in diameter, with an occasional broader one of from 3 to 4^{mm}, as will be seen in the cut. The bands of tænite are broad and quite prominent throughout the mass, the plessite in many places showing these bands crossing them in parallel layers (Laphamite markings). This is shown particularly well on some of the edges of the slices which have been oxidized, giving the tænite a somewhat comb-like effect from their relief above the weathered kamacite.

No schreibersite was noticed by a macroscopical examination. The largest troilite nodule found in any of the sections is not over 2^{mm} in diameter; others range from this down to a fraction of a mm. These latter were quite abundant, as many as sixteen of them being scattered over some of the slices. On the narrow end of three of the slices is a fissure, entirely crossing the slice, filled with troilite.

Some sections show that the oxidation of the surface had extended inward to the depth of 5^{mm} in some places. This readily accounts for the non-appearance of crust on the exterior surface of the mass, as well as the tendency in some portions to scale; also for the limonitic color of the whole.

The examination of this iron by Prof. Shepard, as noted in the article above referred to, was limited to two small pieces—barely an ounce in all—which were from the outer surface, and "had the appearance of pure limonite." It was thus, as he suggests, difficult to obtain either an exact analysis or exact specific gravity. This circumstance sufficiently accounts for the difference between his analysis and the one lately made by Mr. J. M. Davison of Rochester, N. Y. We give both below:

Shepard.		Davison.	
Iron	88·810	Iron	91·25
Nickel	7·278	Nickel	7·85
Cobalt	0·172	Cobalt	·17
Phosphorus	0·120	Phosphorus	·10
	96·580		99·37
Specific gravity, 7·1		Specific gravity, 7·68	

We have given the name of Canyon City to this iron. The town of that name no longer exists, but was known when Prof. Shepard wrote his paper. Mitchell's Atlas, edition of 1885, has Canyon City on the right bank of a branch of Trinity River in the center of Trinity County, lat. 40° 55′ N., lon. 123° 5′ W. It is satisfactory to be able to thus see rescued from the oblivion of uncertainty a meteorite which for more than a quarter of a century has been mistily known by name yet absent and unknown in substance.

ART. XXXVII.—*Two Microscopic-Petrographical Methods;* by FRED EUGENE WRIGHT.

1. "*The Determination of the Relative Index of Refraction of Minerals in Thin Section.*"*

THE relative index of refraction of two adjacent minerals in thin section can be determined under the microscope in three different ways. (1) By their relative relief, and also by the degree of apparent roughness of their surface (shagreened surface). (2) By the method of Becke's line,† whereby under high power a narrow bright band of light can be seen to travel back and forth, toward and away from one of the two minerals at their intersection as the microscope tube is raised and lowered: the rule then holding good that Becke's line moves toward the mineral with higher index of refraction on raising the microscope tube. This method is sensitive and extremely simple. The only objections to it are that in certain cases two such lines can be seen moving in opposite directions, whereupon it is difficult to decide as to the correct one, and that a certain amount of time is expended in changing from low power to high power. (3) By the method described below, which does not exhibit the two lines occasionally seen in the Becke's method, is equally sensitive and does not require the change from low to high power.

The method is based on principles developed by J. L. C. Schroeder van der Kolk in his recent "Tabellen zur mikroskopischen Bestimmung der Mineralien nach ihrem Brechungsindex,"‡ and is but an application of the same to minerals in thin section.

Mr. Schroeder van der Kolk determines the index of refraction of a mineral by submerging small fragments of the same in a liquid whose index of refraction can be lowered or raised by addition of other liquids until it coincides with that of the mineral, and then measuring the index of refraction of the mixture on a total reflectometer. The method is exact to the second decimal place. Mr. Schroeder van der Kolk gives in his Tabellen a list of over 300 minerals arranged according to their refractive index, and also a list of sixteen or more liquids of variable refractive index suitable to be used in connection with his method.

In actual practice, small fragments more or less lenticular in shape are taken and placed in one of the fluids. If its refrac-

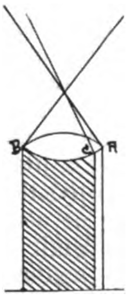
* Compare Tschermak's Miner. Petrogr. Mittheil., vol. xxi, page 238, 1901.

† Sitzungsberichte d. Kaiser. Akademie d. Wissenschaften., vol. cii, page 358-376, 1893.

‡ Wiesbaden, C. W. Kreidels Verlag, 1900.

tive index be higher than that of the liquid, it will act as a lens on the transmitted light and tend to converge the light toward the center (fig. 1); if lower than the surrounding liquid, the effect will be reversed (fig. 2). By cutting off a part of the rays (shaded parts of figs. 1 and 2) the light becomes one-sided in its effect and then exhibits characteristic phenomena. If the fragment AB (fig. 1) be observed under the microscope, the edge AC of the mineral just protruding from the darkened space BC into the light will not be reached by so many beams of light as the surrounding field, and hence will appear darker.

1



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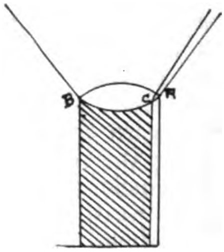


In fig. 2, however, the reverse is the case; the point A just outside the dark field is lighted by all the beams between A and C which are thrown together by the influence of the minerals; A will, therefore, appear brighter than the surrounding field. Moreover, as the dispersion is usually much greater for fluids than for solids, it may happen that if the refractive index for yellow rays is the same as that of the enclosing liquid, its index of refraction for red may be lower and for blue rays higher, in which case the mineral acts as a lens for the red rays and converges them toward the center (fig. 1), while the blue rays will be concentrated along the outer edge, A, which will then appear blue. When, therefore, the refractive indices of mineral and liquid are practically the same, bright colored bands appear along the edge of the mineral. Mr. Schroeder van der Kolk describes several experiments which show this phenomenon in an elegant manner. He darkens half the field by placing a small platinum plate over one half the condenser lens beneath the stage.

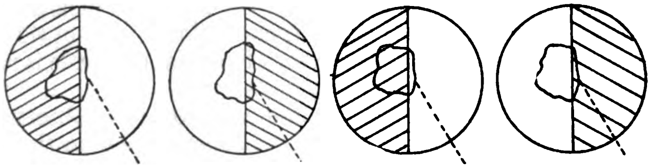
An adaption of this method, which can be effected with but slight changes, has been found serviceable in petrographic work. In the practical application of the method, the low power is used, condenser lens slightly lowered, and half the field darkened, not by means of the platinum plate mentioned above, but by placing the finger in front of the reflector below the stage and thus casting a shadow over any desired part of the field. The same effect can be produced by moving the

lower iris diaphragm found on some microscopes back and forth, or by using a stop diaphragm. The finger, however, furnishes the simplest means and after some practice is used almost unconsciously. Having thus covered half the field in shadow, observe the mineral section on the border of the shadow. If the mineral projects from the shadow into the light field, and appears still lighter and brighter, its refractive index is lower than that of the adjacent mineral. If the mineral lies within the light field and its edge protrudes slightly into the darkened half, the phenomena are reversed. The four diagrams (3, 4, 5, and 6) show the possible cases which may result.

Index of Refraction.

Lower **Higher**

3 **4** **5** **6**



Edge brighter darker darker brighter.

than that of adjacent mineral.

If the refractive indices of the two are about the same, the colored bands, described above, can often be seen. (Quartz and Canada balsam.)

The phenomena described above are distinct and easy recognizable. By placing the finger before the reflector and lowering the condenser lens slightly, the relative index of refraction of two adjacent minerals can be determined accurately.*

In the diagnosis of minute crystals (as chromite crystals within plates of olivine, etc.) the method has been used to advantage.

2. *On the Use of the Optic Normal in the Microscopic Determination of Minerals.*

Method for Determining the Optical Character of an Anisotropic Mineral on a Section Perpendicular to the Optic Normal. ($\mathfrak{b}$ ellipsoidal axis.)

In the thin section the only plates of an anisotropic mineral which can be recognized readily by their optical characteristics

*Mr. Geo. W. Corey of the Michigan College of Mines has recently called the attention of the writer to the fact that the relative refractive index of adjacent minerals in the thin section can be ascertained by this method without the aid of the microscope. Observe the thin section with a pocket lens, holding the slide up toward the sky; by placing the finger in front of the thin section and thus casting a shadow over part of the field, the relative index of refraction of two adjacent minerals can be determined by the rules given above; the phenomena observed are identical with those already described.

are those cut perpendicular to the three ellipsoidal axes $\mathfrak{a}$, $\mathfrak{b}$, $\mathfrak{c}$, and the two optic axes (optic binormals); in the uniaxial minerals these quantities reduce to plates cut parallel and perpendicular to the principal axis.

By observing the interference figures on plates perpendicular to the bisectrices $\mathfrak{a}$ or $\mathfrak{c}$ of biaxial minerals, we are able to separate the biaxial minerals from the uniaxial. The optical character of the uniaxial minerals whether positive or negative can always be determined, while in the biaxial minerals this can only be effected when the angle between the optic axes in air (2 E) is small (less than 90°)—when both optic axes appear in the field, the angle of which is 70°–90° in ordinary microscopes. For the larger part of biaxial minerals, however, 2 E is greater than 90° and cannot be used as a general factor in the practical separation of minerals by ordinary means. The same holds true for plates cut perpendicular to the optic axes. For this reason the optical character of biaxial minerals is rarely applied in their microscopic diagnosis.

By using the interference phenomena, however, observed in convergent polarized light on plates perpendicular to the optic normal ($\mathfrak{b}$ ellipsoidal axis in the biaxial minerals, and the normal to the principal axis in the uniaxial minerals), the optical character of the rock-forming minerals can be ascertained by ordinary means.

A plate perpendicular to the optic normal (either uniaxial or biaxial) exhibits a peculiar interference figure in convergent polarized light. On revolving the stage of the microscope, the field becomes dark suddenly, remains so for an instant, only to become light again on further revolution through a few degrees. In the position of darkness the ellipsoidal axes $\mathfrak{a}$ and $\mathfrak{b}$ are parallel to the plane of vibration of the nicols. No distinct cross is seen as in the interference figures of plates perpendicular to the bisectrices. The entire field appears dark, with perhaps a weak fringe of light along the outer extremities of the diagonals of the quadrants.

If the field be placed in the dark position and turned slightly, faint, dark hyperbolas can be seen to open and leave the center of the field, similar to the dark hyperbolas of the biaxial interference figures perpendicular to the bisectrices, the chief difference between the two being one of intensity and rapidity of motion. The hyberbolas are very weak and require close observation to be noticed at all. A mineral plate of low birefraction will show them less distinctly than one of high.

Rule.—The dark hyperbolas leave the field in the direction of the acute bisectrix in the biaxial minerals and in the direction of the principal axis in the uniaxial minerals.

Application.—Observe direction in which the faint hyper-

bolas of the interference figure of an optic normal in convergent polarized light leave the field on a slight revolution from position of darkness. Determine value of this ellipsoidal axis (whether $\mathfrak{a}$ or $\mathfrak{c}$) by means of quartz wedge in parallel polarized light and with it the optical character of the mineral; on the same section the birefringence $(\gamma-\alpha)$ can also be ascertained; and in monoclinic and triclinic crystals an angle of extinction in general be measured.

Proof.—In uniaxial minerals, the rays travelling parallel to the principal axis suffer no double refraction. The height of the birefringence increases with the angle which the incident ray makes with the principal axis. On observing a section cut parallel to the principal axis in convergent polarized light, the center of the field will become bright for only a slight turn of the stage from the position of darkness, while those rays nearer the principal axis will become less bright for the same angle of revolution. Hence, on rotating the stage from position of darkness of mineral plate to light, the dark weak hyperbolas (less brightly lighted portion) appear to move out in the direction of the least double refraction, i. e. direction of the principal axis.

In the biaxial minerals the acute bisectrix is, in general, direction of lower birefringence than the obtuse. The faint hyperbolas observed in convergent polarized light on a plate parallel to the bisectrices (perpendicular to the $\mathfrak{b}$ ellipsoidal axis) will, therefore, leave the field in the direction of the acute bisectrix.

The statement that the acute bisectrix in biaxial minerals is direction of less double refraction than the obtuse bisectrix can be proved by elementary means as follows:

Let V be the angle which one optic binormal (optic axis) makes with the least ellipsoidal axis $\mathfrak{c}$ and α, β, γ, the three indices of refraction.

The equation

$$\cos^2 V = \frac{\frac{1}{\beta^2} - \frac{1}{\gamma^2}}{\frac{1}{\alpha^2} - \frac{1}{\gamma^2}} \ast \qquad (1)$$

which express the relation between the angle V and the indices of refraction, reduces, for $V = 45°$, to the form

$$\cos^2 V = \tfrac{1}{2}, \text{ or}$$

$$\frac{\frac{1}{\beta^2} - \frac{1}{\gamma^2}}{\frac{1}{\alpha^2} - \frac{1}{\gamma^2}} = \tfrac{1}{2}$$

* Rosenbusch-Iddings, "Microscopical Physiography of Rock-forming Minerals," 1908, p. 38.

If $\mathfrak{c}$ be acute bisectrix, then

$$V < 45^\circ$$
$$\cos^2 V > \tfrac{1}{2}, \text{ and, therefore,}$$

$$\frac{\frac{1}{\beta^2} - \frac{1}{\gamma^2}}{\frac{1}{\alpha^2} - \frac{1}{\gamma^2}} > \tfrac{1}{2} \tag{2}$$

Let

$$\begin{aligned} \beta - \alpha &= C \\ \gamma - \beta &= A, \text{ or} \\ \alpha &= \beta - C \\ \gamma &= \beta + A \\ \gamma - \alpha &= C + A \end{aligned}$$

The expression (2) may now be written

$$2(\beta - C)^2 A(2\beta + A) > \beta^2 (C + A)\ (2\beta + A - C). \tag{3}$$

On rearranging the quantities of (3), we obtain

$$2\beta(A - C)(\beta^2 - 2CA) + \beta^2(C - A)^2 + 2C^2A^2 - 6\beta^2CA > 0 \tag{4}$$

To prove that in the case of $\mathfrak{c}$ acute bisectrix

$$\beta - \alpha < \gamma - \beta$$
$$C < A$$
$$A - C > 0.$$

The value of the expression (4) is evidently dependent on the value of $A - C$, for both A and C are such small quantities (fractions compared to β) that the members of (4) $\beta^2(C - A)^2 + 2C^2A^2 - 4\beta CA$ and usually $6\beta^2 CA$ may be neglected in comparison with $2\beta^3(A - C)$. The value of the expression whether greater or less than zero, depends, therefore, generally on the sign of $A - C$ as $2\beta^3$ is always +. Thus when $\mathfrak{c}$ is acute bisectrix, in general

$$A - C > 0, \text{ or } \beta - \alpha < \gamma - \beta.$$

Hence, the acute bisectrix is, in general, direction of least birefraction. An examination of the list of all biaxial rock-forming minerals confirmed this statement.

Application.—In measuring the extinction angle in any monoclinic mineral in which $\mathfrak{b} = b$, the optical character of the mineral can also be determined at the same time by the above method. The birefringence $(\gamma - \alpha)$ can likewise be ascertained on the same plate if its thickness be known. The plate cut perpendicular to the optic normal exhibits the strongest double refraction (highest, brightest interference colors), and can be picked out readily from a number of plates of the same mineral cut along various planes. Thus a plate of monoclinic

amphibole or pyroxene ($\mathfrak{b}=\mathfrak{b}$) parallel to the clinopinacoid 010, on which the extinction angle must be measured, is also suitable to reveal the optical character of the mineral and the double refraction ($\gamma-\alpha$).

Determination of the plagioclase feldspars:

Cleavage faces parallel to the basal pinacoid 001 of the soda-lime feldspars (acid plagioclase), albite to basic andesine, show the optic normal more or less distinctly, and can be determined by the above method as such without further trouble. With this aid in the diagnosis, the separation of the acid plagioclases by the cleavage method on plates parallel to the base (striæ after the albite law) is rendered more certain, as the ambiguity of the sign of extinction is largely eliminated. (The feldspars $Ab_1An_0-Ab_8An_1$ are positive; $Ab_8An_1-Ab_{22}An_{10}$, negative; $Ab_{22}An_{10}-Ab_1An_4$, positive; $Ab_1An_4-Ab_0An_1$, negative.)

In his "Etude sur la Determination des Feldspaths," Michel Levy has plotted a curve illustrating the extinction angles on plagioclase feldspars cut perpendicular to the optic normal ($\mathfrak{b}$, n_m). Unfortunately, the values are so nearly equal in the acid plagioclases that an exact separation of the same is not possible by this method alone. The ambiguity, however, arising from the plus or minus character of the angle between albite and oligoclase and andesine can, in general, be eliminated by the method described above. In the determination of the plagioclase feldspar by the method of Michel Levy in conjunction with the above, a plate cut perpendicular to the optic normal (highest interference color) is first selected, its angle of extinction (angle between the least ellipsoidal axis and the twinning lamellae) measured, the direction of the acute bisectrix noted and its relative value, whether $\mathfrak{a}$ or $\mathfrak{c}$, ascertained by means of the quartz wedge. By combining the extinction angle of any plagioclase with its optical character, the feldspar can in general be determined accurately.

Michigan Geological Survey, Houghton, Michigan.

ART. XXXVIII.—*On the Denucleating Effect of Rotation in case of Air Stored over Water;* by C. BARUS and A. E. WATSON.

1. THE following interesting result was obtained incidentally, in connection with other researches.

If air containing nuclei from any source whatever is introduced into a cylindrical condensation chamber over pure water, and if the cylinder is rotated on its axis more or less rapidly, without further interference with the air contained, the charge of moist air will soon be found to be free from nuclei.

2. The following are examples of the results obtained. Nuclei were produced in dust-free air by passing the X-rays through a cask of paraffined wood, in the direction of an equatorial diameter, for three to five minutes. The cask was 35^{cm} in diameter and 40^{cm} long, mounted axially on an axle and turned by a small electromotor. The coronas were viewed through two longitudinal and diametrically opposite strips of plate glass. Details of construction cannot be considered here; we need merely state that the apparatus during rotation was absolutely free from leakages of nuclei, either of efflux or of influx.

The size of the corona due to nuclei generated by the X-rays is unfortunately very variable, depending (caet. par.) on conditions of radiation beyond the observer's control. Diameters ranging on an arbitrary scale from 6 to 12^{cm} were obtained for the case of rather weak radiation, passing for three to five minutes through the wood of the stationary cask. As a rule, the nuclei vanish in less than three minutes of moderately fast rotation (two turns per second), and the corona obtained thereafter is almost too weak for detection. At these speeds the whole of the water does not yet adhere as a smooth cylindrical apparently rigid sheet to the sides of the cask, but is carried around with more or less turbulent motion.

TABLE I.—Number of nuclei, n, per cub. cm. before and after rotation. Pressure difference about 22^{cm}. Nuclei produced by X-rays to the average number of 30,000 to 70,000 per cub. cm.

Experiment No.	Time of radiation. min.	Time of rotation. min.	Turns per min.	Arbitrary diameter of corona. cm.	n nuclei per cub. cm.
1	3	0	0	4·1	27000
	—	2	140	1·8	2500
	—	4	140	·0	0
2	4	0	0	5·6	69000
	—	6	120	1·1	500
3	3	0	0	1·8	2300
	—	3	64	·0	0
4	3	0	0	2·1	3600
	—	3	230	·5	50

Two reasons may be suggested for the cleansing effect of rotation: It is supposable that eddy currents are produced by the rotation, as a result of which all parts of the confined air are in succession washed on the surrounding surface of water. Such currents, however, could hardly persist but for a short time after the beginning of the rotation. In the second place, if there is churning of the pure water connected with the rotation, the enclosed air must pass in small bubbles through the water many times. This seems to be the more potent cause for the absorption of nuclei. The details of the experiments with X-ray nuclei did not conform very closely with either of these hypotheses, and we therefore decided to investigate the question thoroughly with a larger type of coronas and in a large glass vessel, through which the whole behavior could be better seen.

3. The following results were obtained with a glass cylinder about 35^{cm} long and 25^{cm} in diameter (part of an old electrical machine). It was nicely mounted axially and capable of very rapid rotation, enabling the observer to catch up the whole of

TABLE II.—Air nuclei removed by rotation. $\delta p = 17^{cm}$. Goniometer and lamp 85^{cm} and 250^{cm}, resp. from chamber.

Remarks.	Time of successive rotations. min.	Turns per minute.	s cm.	n nuclei per cub. cm.
Water in a *smooth*	0	? 450	10	(200,000)
cylindrical shell ;	3		6·4	85,000
fixed to glass walls.	3		6·1	74,000
	4		5·6	57,000
Water in very turbu-	0	350	7·6	140,000
lent motion.	3		3·3	12,000
	3		2·1	3,000
	3		1·2	500
Water in turbulent	0	150	8·8	(160,000)
motion.	3		5·6	57,000
	3		5·4	51,000
	3		4·2	24,000
	3		3·3	13,000
	3		2·8	7,000
	3		2·1	3,000
Time loss of nuclei	0	0	8·7	(160,000)
without rotation.	3		6·8	100,000
Slight subsidence of	3		6·2	77,000
the successive fogs.	3		6·2	77,000

Note: Corrections for periodicity were not applied as it did not seem necessary. The results are thus somewhat irregular. The numbers in parenthesis are estimated.

the enclosed pure water centrifugally, or but a part of it, at pleasure. The difference of the rotational resistances for the two cases is noteworthy.

The angular diameter, θ, of the coronas was determined with a goniometer having a radius $R = 30^{cm}$ long, so that if s is the chord corresponding to R, $\tan \theta/2 = s/2R$. Goniometer and source of light were 85 and 250^{cm}, respectively, from the cylinder, and the exhaustions all corresponded to the pressure difference of about $\delta p = 17^{cm}$, at about 20°.

The results are definite. The first and last parts of Table II show that the time loss of nuclei when the cylinder is rotating so rapidly that the water is held up as a *smooth sheet* against its sides, is not much larger than when the cylinder is stationary, in spite of the fact that in the first case some nuclei must be lost in the turbulent motion on starting and stopping. The law of decrease is as usual apparently geometric.

When the critical speed at which water is caught up on the sides is not attained, in other words, when only a part of the water contained is carried around by rotation, then the cleansing effect is very marked as the middle parts of the table show. Furthermore, nuclei are lost more rapidly per minute as the speed of rotation producing turbulent motion is greater.

Thus it follows that the nuclei are lost by the continued bubbling of the air enclosed within the cylinder through the water contained. This rotational method of making the air dust-free is frequently very convenient, particularly in those cases where slow rotation of the condensation chamber is necessary to keep the air within saturated, and in other cases to be treated elsewhere.

In conclusion, we may observe that if the continuous passage of air in bubbles through water produces ions (as has been shown by J. J. Thomson, Himstedt and others), these ions are not in evidence in the role of condensation nuclei; for the effect of churning pure water, far from being a means of generating nuclei, has in the above experiments been shown to be a very effective method of making the air dust-free. From this point of view we regard the experiments as noteworthy.

Brown University, Providence, R. I.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Blue Color of Basic Lanthanum Acetate and Iodine.*—The very remarkable reaction, similar to that of starch, which basic lanthanum acetate gives with free iodine was observed by Damour in 1857, and has been frequently applied for the qualitative detection of the rare earth. The reaction has been studied recently by W. Biltz, who finds that it does not take place when the nitrate is used, and that it is dependent to a large degree upon the physical condition of the precipitate, which should possess the semi-transparent appearance of a colloidal substance. A product that is more pulverulent and white, such as is usually obtained from boiling acetate solutions, gives only a brown color with iodine. After the blue product is once formed, however, the liquid in which it is suspended may be heated to a higher temperature without injury to the color. An addition of indifferent electrolytes, such as potassium nitrate, is also without injurious action, so that the reaction may be obtained from solutions of lanthanum nitrate which have been acidified with acetic acid before precipitation. The reaction always appears with certainty when a solution of iodine in potassium iodide is added to a lanthanum acetate solution, and then enough ammonia is added cautiously, so that the brownish yellow color of iodine does not quite disappear, and finally the liquid is heated very gently. A dark blue precipitate gradually forms, or, if the solution is very dilute, a blue colored liquid is obtained. Quantitative experiments showed that the amount of iodine taken up by the precipitate is very nearly proportional to total amount present in the liquid; hence the conclusion is reached that the phenomenon, like the formation of iodized starch, is one of adsorption, and that the blue substance is not a definite compound.—*Berichte*, xxxvii, 719. H. L. W.

2. *Yellow Antimony.*—It has been known for many years that an unstable, yellow form of arsenic exists, which is analogous to yellow phosphorus. Stock and Guttmann have now succeeded in preparing a yellow modification of antimony by the action of air or oxygen upon liquid hydrogen antimonide at $-90°$. The substance is spontaneously transformed into the black form even more readily than yellow arsenic; for the change takes place in a few seconds even at $-50°$, and even at the temperature of its formation, $-90°$, it is so unstable as to become brownish or blackish in a few hours. The oxidation of hydrogen antimonide at the low temperature used for the preparation of the substance is very slow, so that the yield is small. It was shown that the yellow substance does not contain hydrogen, and that it is soluble in carbon bisulphide at a temperature somewhat higher than $-90°$, giving a strong yellow color to the solution. Imme-

diately after this solution takes place, separation of black antimony begins.—*Berichte*, xxxvii, 898. H. L. W.

3. *Action of Carbon upon Lime at the Temperature of Fusing Platinum.*—MOISSAN has heated a mixture of sugar-charcoal and quick-lime in the proportions for the formation of CaC_2, in a tube made of fused quartz, by means of an oxygen and illuminating gas blowpipe flame, to the temperature at which platinum fuses, and has found that at this temperature not a trace of calcium carbide is formed. In this connection the observation was made that silica possesses, even below its point of fusion, an appreciable vapor tension, for at 1200° there were slowly formed upon the lime small needles of an insoluble calcium silicate, a circumstance which prevents the frequent use of a tube of this kind. It was observed also that crystals of calcium carbide were not changed at the fusing-point of platinum, while platinum wire melted at once in solidifying calcium carbide.—*Comptes Rendus*, cxxxviii, 243. H. L. W.

4. *Two Sodium-Ferric Sulphates.* — SKRABAL has prepared two double salts, one basic and the other normal in composition, which are interesting from the fact that they correspond to known minerals.

The compound $FeSO_4OH . Na_2SO_4 . 3H_2O$, which agrees in composition with the mineral sideronatrite, is a pale yellow precipitate formed by heating a solution of 50 g. of ferric sulphate acidified with 10^{cc} of dilute (1:6) sulphuric acid and 300 g. of Glauber's salt. The other compound, $Fe_2(SO_4)_3 . 3Na_2SO_4 . 6H_2O$, which corresponds to the mineral ferronatrite, was prepared from a very concentrated solution of 10 g. of ferric sulphate, 100 g. of Glauber's salt and 15^{cc} of concentrated sulphuric acid. This compound is a colorless precipitate.—*Zeitschr. anorgan. Chem.*, xxxviii, 319. H. L. W.

5. *Grundlinien der Anorganischen Chemie*, von WILHELM OSTWALD. Zweite, verbesserte Auflage. 8vo, pp. 808. Leipzig, 1904 (Engelmann).—The first edition of this text-book of elementary inorganic chemistry appeared in 1900. The prompt appearance of this new edition is due in some measure to the fact that 4000 copies of the first edition were sold within three years, and no further comment is needed to show the approval of the chemical public, in Germany at least, in regard to the treatment of elementary chemistry from the standpoint of modern physical chemistry.

No very marked changes have been made in the new edition—the increase in volume amounts to thirteen pages. The author continues to maintain his curious opposition to the atomic and molecular hypotheses, although in this edition he calls molecular weights "molar-weights" in place of the still more ambiguous "normal-weights" of the other edition. It seems entirely inconsistent that he should believe so implicitly in ions but not in atoms and molecules.

Some of the numerous errors of the original book have now

disappeared, but there is no difficulty in finding them here. For instance, the reaction of hydrogen sulphide upon heated copper is given as $H_2S + Cu = CuS + H_2$, whereas it is very well known that Cu_2S would be formed; it is stated that lead tetra-acetate is a yellow salt, instead of a colorless one; and there are several errors in connection with metallurgical topics. H. L. W.

6. *A Manual of Qualitative Chemical Analysis;* by J. F. McGregory. 8vo, pp. xiv, 133. Boston, 1903 (Ginn & Company).—This text-book has been prepared to meet the wants of the author's own classes, as has usually been the case with the great number of books on this subject that have already appeared. Their number shows the existence of much diversity of opinion in regard to the best methods of teaching this branch of chemistry. The book under consideration gives a rather extensive course in the reactions of the radicals, and it seems that all of these are expected to be mastered before their analytical application is taken up. The learning of all these details without applying the knowledge and thus connecting it with analytical processes, is an exceedingly difficult matter, and it appears to the reviewer that this feature is objectionable. The attempt to avoid purely mechanical work on the part of the student by omitting tabular outlines of methods is praiseworthy. The following sweeping statement in the introduction leaves no place for the elements themselves, nor for the many "simple" inorganic substances which are neither acids, bases, nor salts: "Every simple inorganic substance consists of two parts. The first, which is a metal or positive radical, is chemically combined with the second, which is a non-metal or negative radical." The book is marred by the so-called reformed chemical spelling, which leads to incorrect pronunciation and is not in harmony with the rest of the English language as it is now written. H. L. W.

7. *Influence of Temperature and Pressure on the Absorption and Diffusion of Hydrogen by Palladium.*—The following conclusions have been reached by G. N. St. Schmidt: The absorption of hydrogen by palladium follows the phenomena of most absorbing substances above 140° C. That is, it increases with the pressure and diminishes with the temperature. The diffusion increases with the temperature and with the pressure.

This is not true under 140° C. Here enters an irregularity. We are accustomed to consider that in the course of diffusion of a gas through a solid body that first adsorption takes place, then absorption, then diffusion. Diffusion then can only take place if the gas is in the first place adsorbed by the solid body; and this happens only when a certain affinity exists. We must, therefore, assume that under 140° C. no affinity exists between hydrogen and palladium. This enters first at higher temperatures and with it adsorption. There are analogies in chemistry: for instance, carbon and nitrogen do not combine at ordinary temperatures; but at high temperature form CN.

Winkelman has found (Ann. d. Phys., 6, p. 104, 1901; 8, p. 338, 1902) that the amount of diffusion of hydrogen through palladium and platinum is not proportional to the pressure but is relatively greater with diminishing pressure. He explains this by the theory that the diffusion enters with a dissociation of hydrogen molecules and that only the hydrogen atom diffuses. This narrows the working pressure. The forcing pressure is dependent upon the difference of the adsorption on both sides of the body. The diffusing quantity is proportional to this difference. Since it is not shown that this difference is strictly proportional to the pressure, and observations prove that it more or less diminishes with the latter, it necessarily follows that the diffusing quantity is not narrowly proportional to the pressure. The theory that the forcing pressure changes through dissociation of the hydrogen molecule does not appear to be an explanation of the observed irregularity.—*Ann. d. Phys.*, 4, 1904, pp. 747–769.

J. T.

8. *Study of the Radio-activity of Certain Minerals and Mineral Waters.*—In a paper on this subject delivered by the Hon. R. J. STRUTT before the Royal Society, there is the following interesting estimate of the quantity of radium in Bath water:

"According to the estimate of Sir A. C. Ramsay, the late Director of the Geological Survey, the salt annually delivered by the Bath spring would be equivalent in volume to a column 9 feet in diameter and 140 feet high. Taking the density to be twice that of water, this would weigh about 500,000 kilograms. The saline residue gives about one-fifteenth the part of the quantity of emanation that samarskite gives. Let us assume that the latter contains one-millionth part of radium, which I think is an outside estimate. At that rate the annual delivery of radium by the spring amounts to about one-third of a gram. The volume of gas which the spring delivered is about one hundred cubic feet per day (Williamson, Brit. Assoc. Reports, 1865, p. 380).

About one-thousandth part of this is helium, so that about three liters of helium are given off daily, or about one thousand liters per annum. The proportion of helium to radium thus indicated is of the same order as in radio-active minerals, though somewhat larger. This is in accordance with the view that the spring draws its supplies from the disintegration of such minerals."—*Nature*, March 27, 1904. J. T.

9. *Atmospheric Radio-activity in High Latitudes.* — A series of determinations of the radio-activity of the atmosphere have been made by G. C. SIMPSON at Karasjoh, Norway, in 69° 20′ N. lat. It was found that the radio-activity was very much greater than in lower latitudes; the mean for the month being 102, or about six times as great as the German mean for the year (Elster and Geitel at Wolfenbüttel), while the highest value was 432 or nearly seven times the German maximum. As regards the connection with time of day, the maximum was found to fall in the evening, the means for morning and afternoon being

nearly the same. No direct relation was found between the radio-activity and the potential-gradient; temperature and barometric pressure also seemed to have no great influence. The presence of clouds had a marked effect, however, the maximum of 432, for a clear sky, falling to 198, when the sky was completely overcast. Sudden changes were occasionally noted, as from the low value 66 to the high 384 within a few hours. The observations were made in winter when the sun was below the horizon and the surface of the frozen earth was covered with more than two feet of snow.—*Proc. Roy. Soc.*, lxxiii, 209.

10. *The Optical Properties of Vitreous Silica.*—The remarkable properties of vitrified quartz which make it suitable for certain applications in optical work are remarked by GIFFORD and SHENSTONE. It has a definite constant composition, unlike glass; is hardly attacked by any corrosive fumes (except F and HF) and is indifferent to solvents. It is also as transparent to ultraviolet radiation as quartz while it has not its double refraction. Its dispersive power is sensibly greater than that of quartz, while the refractive index is low, approaching that of fluorite. A 60° prism, 41^{mm} high by 32^{mm} wide, was made with great care from many hundreds of fine rods of vitreous silica. Another compound prism, $56^{mm} \times 38^{mm}$, was made of four distinct slabs of silica from separate meltings; when finished its performance could not be distinguished from the single prism. Values of the refractive indices for the latter prism are given for a series of wave-lengths from 7950 to 1852·2; for D (Na) the value obtained was 1·4584772. For a thin doublet of fluorite achromatized by vitreous silica it was found that the focal length was almost independent of wave-length.—*Proc. Roy. Soc.*, lxxiii, 201.

11. *Terrestrial Magnetism.*—A Department of International Research in Terrestrial Magnetism has been established by the Trustees of the Carnegie Institution. An appropriation of $20,000 was made for the organization of the work and an annual grant of like amount is expected for carrying it on. Dr. L. A. Bauer, who now has charge of the magnetic work of the Coast and Geodetic Survey, has been appointed Director of the new Department.

II. GEOLOGY AND NATURAL HISTORY.

1. *United States Geological Survey.*—The following publications have recently been issued:

TWENTY-FOURTH ANNUAL REPORT, 1902–1903; by C. D. WALCOTT, Director. 230 pp., 26 pls.—The amount of work under direction of the Geological Survey may be judged from the size of the appropriation, which last year amounted to $1,377,470. For purely geologic work there was allotted $163,700. A section of Petrology has been created, with Mr. Whitman Cross as geologist in charge. The principles of classification and nomenclature adopted in 1889 have been revised and a new code of

regulations for the making of the Geologic Atlas has been promulgated (pp. 21–28). A special appropriation of $60,000 made it possible to send five field parties into Alaska and the expansion of the work led the Secretary of the Interior to create a Division of Alaskan Mineral Resources in charge of Mr. A. H. Brooks. The section of Physics is conducting experiments upon the behavior of rock-forming minerals and upon the force exerted by growing crystals. Plans have been completed by Dr. A. L. Day and equipment provided for enlarging the scope of this work. The hydrographic work of the United States has reached enormous proportions since the law regarding the reclamation of arid lands was passed. Four divisions now constitute the hydrographic branch—hydrography, hydrology, hydro-economics and reclamation service; and the funds available for this work and not included in the appropriation for the Geological Survey amount to over $3,000,000 annually. The Survey has more than ever the confidence of the scientific and business world.

MONOGRAPH No. XLVI. The Menominee Iron-Bearing District of Michigan; by WILLIAM SHIRLEY BAYLEY. 513 pp., 43 pls., 54 figs.—This is the sixth and the last of the series of monographs to be published, dealing with the separate iron-bearing districts of the Lake Superior region. Another volume devoted to the general geology of the Lake Superior region as a whole is to follow.

The Menominee district forms a narrow tongue with an area of 112 square miles on the Michigan side of the Menominee River. It has been an important factor in the iron ore production since 1877. The district is bordered by areas of Archean schists and granites. The Huronian sediments of the district, in which occur the ore bodies, lie in a trough between these older rocks. Structurally this trough is a synclinorium composed of several important anticlines and synclines. The Huronian rocks are divided into two series called the Upper and Lower Menominee, which are separated from each other by an unconformity. The Lower Menominee series comprises 1,050 to 1,250 feet of quartzites and conglomerates with 1,000 to 1,500 feet of dolomites. The Upper Menominee series comprises the Vulcan formation, 650 feet thick and the Hanbury slate. The Vulcan formation includes three members, the iron-bearing Traders member, consisting largely of detrital ores and jaspilites, but having basal layers of slate, quartzite and conglomerate; the Brier member, composed of ferruginous and siliceous slates and the Curry member, consisting of quartzites, ferruginous quartzose slates, jaspilites and ores.

The larger ore deposits all rest upon relatively impervious foundations which are in such a position as to constitute pitching troughs. The ores of this district, like those of the Gogebic and Marquette districts, were concentrated by descending waters flowing in definite channels and the general processes involved were the same as those worked out by Van Hise for these other districts.

The book is well and abundantly illustrated and is accompanied by two detailed maps of the region. An introductory outline which serves to give a brief summary of the different chapters is included. W. E. F.

BULLETIN No. 208. Descriptive Geology of Nevada South of the Fortieth Parallel and Adjacent Portions of California; by JOSIAH EDWARD SPURR. 222 pp., 8 pls., 22 figs.—One of the gaps in the geologic map of the United States which has been heretofore unfilled is southern Nevada. This area has now been mapped in a preliminary way as part of the plan to publish a new general geologic map of the United States on the scale of about 40 miles to the inch. Mr. Spurr has confined himself to descriptive matter and has included in his bulletin the results of the geological explorations of Wheeler (1866), Gilbert (1871) and other workers.

No. 218. The Coal Resources of the Yukon, Alaska; by ARTHUR J. COLLIER. 67 pp., 6 pls., 3 figs.—Coal of commercial importance is found at many places along the Yukon River. It occurs in sandstones of Eocene and Upper Cretaceous age. The coal thus far mined ranges from high grade lignite to "rather low grade bituminous." The coal beds are sufficient to supply local demands but "will probably never supply coal for exportation." Fossils, many of them entirely new, were collected from fifty-three localities and have been studied by Drs. Stanton and Knowlton and Mr. Schuchert.

No. 219. The Ore Deposits of Tonopah, Nevada; by J. E. SPURR. 28 pp., 1 pl., 4 figs.—A detailed final report of the interesting Tonopah region from which $4,000,000 were taken the first season will be issued later, and the present bulletin gives only general outlines. The rocks in the immediate vicinity of Tonopah are Tertiary andesite, dacite, rhyolite and basalt with accompanying tuffs. The veins occur in the earliest andesite, and after a period of erosion were capped by later lavas. "The veins were formed by ascending waters succeeding and connected with the early andesite intrusion." There were four periods of hot spring action accompanied by vein formation and mineralization and each of these periods was consequent upon lava intrusion. The ore is gold and silver in the proportion of about 1 : 100 and is unusually free from base metals.

No. 220. Mineral Analyses from the Laboratories of the U. S. Geological Survey, 1880 to 1903; tabulated by F. W. CLARKE, chief chemist. 114 pp.—507 analyses of minerals of over 150 distinct species have been collected from the laboratory records, and published in one bulletin for convenient reference.

No. 221. Bibliography and Index of North American Geology, Palæontology, Petrology and Mineralogy for the year 1902; by F. B. WEEKS. 200 pp.

No. 222. Catalogue and Index of the Publications of the Hayden, King, Powell and Wheeler Surveys; by L. F. SCHMECKEBIER. 208 pp.—The early surveys of the Western United States include

Geological and Geographical Survey of the Territories (Hayden) with publications extending from 1867 to 1878; Geological Exploration of the Fortieth Parallel (King), 1871–80; Geographical and Geological Surveys of the Rocky Mountain Region (Powell); Geographical Surveys West of the 100th Meridian (Wheeler). A vast amount of valuable detail is contained in the publications of these early surveys and a complete catalogue and consolidated index make it available. Investigators, students and librarians will receive this bulletin with hearty thanks.

2. *Fossil Footprints of the Jura-Trias of North America;* by RICHARD SWAN LULL, Ph.D. Memoirs of the Boston Society of Natural History, vol. v, number 11; pp. 461–557, with one plate and numerous text-figures.—The subject of the ichnology of the Connecticut River valley, so remarkably developed by Edward Hitchcock in his works of 1848, 1858 and 1865, has received few scientific contributions for the past forty years. During this period, however, the study of the dinosaurs from the west has very greatly extended the knowledge of early reptiles, so that at the present time the conditions are much more favorable than formerly for a proper interpretation of the problematical footprints. The author has made an exhaustive study of the type specimens of Hitchcock, most of them preserved in the collections at Amherst College, and the results are given in this memoir; his conclusions are here quoted in full from the closing pages.

"The creatures, the record of whose existence has remained impressed upon the ancient shales and sandstones, may be divided into two groups in accordance with their mode of progression: those of bipedal and those of quadrupedal gait. The former, it may be safely assumed, are, in all probability, dinosaurs, for aside from man, many birds, and some modern lizards, they are the only vertebrates whose gait when erect could have been a true walk or run with alternating steps, which without exception the bipedal tracks show, there being no instance of the record of a jumping form. The presence of birds in the new red sandstone has not been proven, lizards are never *habitual* bipeds, man is clearly out of the question, hence by elimination we narrow the possible origin of such tracks down to the dinosaurian forms. This conclusion is strengthened by the presence of the fossil bones of the *Anchisauridae,* a family of primitive carnivorous dinosaurs having affinities with the Megalosauria.

The most abundant of the tracks are attributable to members of that family, creatures ranging in size from about seven to fourteen feet, so truly bipedal that the manus and tail never impress. The pes is tetradactyl, but only exceptionally does the claw of the strong grasping hallux leave a mark. The claws are rather pointed and the whole foot is very bird-like. These footprints form a natural group to which the generic name of Anchisauripus is given and which corresponds to the family *Anchisauridae.*

Allied to Anchisauripus is another carnivorous form whose foot is more specialized than that of the former in the enfeeblement of the hallux and increase of weight which has rendered the foot flatter and its pads more complex. This creature, Gigandipus, reminds one strongly of the Jurassic Allosaurus, though in the latter the claws were probably more trenchant and the whole foot more efficient as a grasping organ. Gigandipus, known from but one specimen, shows a sinuous caudal trace. The dragging of the tail probably was not habitual, but occurred only when the animal was slowing down before stopping.

Another abundant genus is Grallator, characterized by very long limbs and small, compact feet without an impressing hallux and with no tail trace. The proportions of length of limbs to those of feet are the same as in the bustards and the forms which made the tracks were probably aberrant carnivores of habits somewhat similar to those of wading birds, possibly feeding upon feebler reptiles and amphibians, or on fish. In considering the probable relationship of this genus to genera known from their skeletal remains, one is reminded strongly of Ornithomimus, a Cretaceous Compsognathoid dinosaur. Grallator comprises for the most part small forms, the smallest species, *G. gracilis*, indicating a creature but two-thirds the size of Compsognathus, the smallest known dinosaur, whose dimensions may be compared with those of the domestic cat.

Among the habitually bipedal forms, those which never impress the manus, is one group to which the name Eubrontes has been given. It includes larger and heavier forms than Anchisauripus with more blunted claws, but Hitchcock included it with the latter under the name Eubrontes and the later name Brontozoum. The two genera are so different in character that the present author is constrained not only to separate them generically but ordinally as well, for the lack of a grasping hallux, the heavy, slow-moving tread, and the blunter claws are surely not carnivorous characteristics, but seem to point rather to an herbivorous habit of life. It may be that instead of being Orthopod or Predentate dinosaurs the Eubrontes represent another group of aberrant Carnivora, which like the condor (*Sarcorhamphus gryphus*), because of carrion-feeding habits, did not retain the raptorial claws of its predacious allies. The genus Eubrontes while few as to species contains some of the most impressive forms which are fairly numerous as to individuals. *Eubrontes giganteus* represents an animal of massive proportions and of about twenty feet in length, which is nearly the maximum for American Triassic dinosaurs, though much inferior in size to those of the Jurassic and Cretaceous periods. Dinosaurs beyond question herbivorous in their habits, and hence belonging to the order Orthopoda, are the occasionally quadrupedal forms which, though walking on the hind feet, placed the fore feet on the ground while sitting. This shows that on both manus and pes the claws are short and rounded and no longer subserve a

grasping function. The particular interest which attaches to this fact is that it is the first evidence we have of Orthopoda or Predentate dinosaurs in the Trias, for their skeletal remains are entirely unknown either in this country or in Europe from the rocks of that period.

Anomoepus, the most characteristic genus among the herbivorous forms, had a pentadactyl manus with rounded claws and a tetradactyl pes with somewhat longer but still blunted claws. The hallux was but half rotated and therefore ill fitted for grasping, and there was a long metatarsus, or heel, on which the creature rested. The tail sometimes dragged just before the owner came to rest, but at other times was held clear of the ground as a counterpoise to the anterior part of the body as in other genera. Anomoepus represents a group of small, lightly built creatures ranging in size from *A. minimus*, about three feet in length, to *A. crassus*, a New Jersey form, six feet long. They are among the most numerous and interesting of all of the ichnite genera with the exception of Anchisauripus.

The genus Fulicopus, which the writer has separated from the preceding group, shows a greater amount of weight borne on the hind limbs while sitting, the manus resting but lightly as with the kangaroo. The feet resemble those of Anchisauripus more than those of Anomoepus, there being less divarication or diverging of the digits, though the position of the hallux is as in the latter genus. A curious heart-shaped impression frequently occurs just behind and between the impressions of the heels, and this was attributed by Hitchcock to the end of a truncated tail, but the writer believes it to have been made by a callosity beneath the apposed extremities of the ischial bones. Hypsilophodon, of the Wealden of Europe, most nearly suggests the probable skeletal characters of the Anomoepodoid forms, and as Professor Osborn has shown, presents the most primitive characters of any known Orthopod. It is difficult to conjecture the probable habits of Anomoepus, other than that the animals were herbivorous. They probably came to the mud flats mainly for breeding purposes, as their tracks very frequently exhibit a distinct sexual dimorphism between the footprints of the two individuals.

A very striking though rare form, Otozoum, has been placed by the present writer among the Orthopoda, although the structure of its foot is unlike that of any known dinosaur. Otozoum is probably bipedal, though there is a possibility that the great pes may have obliterated the track of the much smaller manus. The foot is plantigrade, tetradactyl, with all of the digits pointing forward and with rounded pellet-like claws and a broadly expanding web or fleshy pad extending some distance beyond the ends of the digits. Its probable function was that of supporting the creature on soft mud rather than a natatorial one. The phalangeal formula of the pes is typically dinosaurian, while that of the manus, 2. 3. 3. 3. 3, is amphibian or cotylosaurian and would be absolutely unique in a dinosaur. The manus is rarely seen and is

so obscure that there is a reasonable doubt as to the correctness of its interpretation. In one instance a dragging tail is shown which is absent in all other specimens and which is evidence in favor of the belief that the animal is a biped. Otozoum has the largest track of all, measuring twenty inches in length, but the author has no conception of the appearance of the creature itself.

Among the so-called leptodactylous or narrow-toed tracks, are many made by bipedal forms which were doubtless dinosaurs, some carnivorous, and some, judging from the manus which is occasionally seen, herbivorous in habits. The subsequent slipping of the mud after the withdrawal of the foot has obliterated most of the morphological characters from the impressions. Some of the leptodactylous forms have been identified with the better known genera and species; others which cannot be so identified because of their obscurity may nevertheless be identical with known forms, while still others evidently do not occur elsewhere. It is a notable fact that while the number of genera and species which have been erected upon these impressions is large, the number of individuals represented is proportionately small, and these are mainly from one or two localities.

Of the truly quadrupedal forms the most interesting is Batrachopus, whose long limbs, tetradactyl, plantigrade pes with acuminate claws, and phalangeal formula of 2. 3. 4. 5, and whose pentadactyl manus are such as one would expect to find in the dinosaurian ancestor. It seems possible, therefore, that Batrachopus represents a persistent type whose affinities are near the dinosaur stem form and which should be classed with Kadaliosaurus in the superorder Diaptosauria of Osborn. Batrachopus may have been a true dinosaur which had retained, among other primitive characters, the ancestral quadrupedal gait. The mode of progression was a true walk like that of a mammal and not the sprawling crawl of modern reptiles. Batrachopus included small forms of carnivorous habits.

There remain other quadrupedal forms, generally of small size, whose tracks, aside from the number of digits, size of the foot, and the length of limb, afford almost no date whereon to base a theory as to their affinities. Professor Osborn has likened ichnological interpretation to the deciphering of ancient cuneiform inscriptions which are utterly unintelligible unless one possesses the key. That the key to the deciphering of the dinosauroid tracks has been found seems evident, but in the attempt at the interpretation of the obscurer quadrupedal footprints the student is still very much in the dark."

3. *The Non-metallic Minerals; their Occurrence and Uses;* by GEORGE P. MERRILL, Head Curator of Geology in the U. S. National Museum, etc. Pp. xi, 414. New York, 1904 (John Wiley & Sons).—This work has grown out of the author's Guide to the Collections in Applied Geology in the U. S. National Museum. While it does not attempt to be a complete text-book, it brings together a large amount of interesting data in regard

to the uses of the non-metallic minerals and their occurrence and mining, particularly with reference to the localities in this country. The mineralogist will find it a useful and instructive volume to accompany the usual text-books, and to the practical worker it will be an almost indispensable compendium of information not easily found elsewhere. A series of thirty-two plates are introduced in addition to text figures; many of these are devoted to views of mineral quarries.

4. *Lehrbuch der Mineralogie;* von MAX BAUER. Zweite, völlig neubearbeitete Auflage. Mit 670 figuren. Pp. xii, 924. Stuttgart, 1904 (E. Nägele).—This second edition of the well-known text-book by Professor Bauer gives evidence in its size of the progress which the science has made since the first edition was published in 1886. The volume now runs to nearly one thousand pages, of which about one-half are devoted to the physical and chemical characters of the species. The matter has been rewritten throughout from the modern standpoint and brought strictly up to date, as is particularly obvious in the chapters devoted to Crystallography. The descriptions of species are full and the general statement of characters which precedes each group adds much to the clearness of the whole discussion.

5. *Annual Bulletin of the Mineral Resources of Kansas,* 1903; by ERASMUS HAWORTH, State Geologist. Pp. 135, Lawrence, Kansas, 1903 (The University Geological Survey of Kansas).—The total production of the mining metallurgical industries of Kansas amounted to over $23,000,000 in 1902, a much larger sum than has been reached before. The most important developments of the year were in the production of coal, the yield of which was upward of 5,000,000 tons, and also of oil and gas from localities in the southeastern part of the state.

6. *A Bibliography of the Geology, Mineralogy and Paleontology of Brazil;* by JOHN C. BRANNER. Pp. 115, 4to. From vol. xii of the Archivos do Museu Nacional do Rio de Janeiro, 1903.—This is the first comprehensive bibliography of the geology of Brazil and contains 1203 titles, not including abstracts and reviews. The author remarks that the great bulk of the geological work in the country has been done by Eschwege and by Derby, the influence of the latter having been particularly important.

7. *The Willamette Meteorite;* by HENRY A. WARD. Proceedings of the Rochester Academy of Science, iv, pp. 137–148.—The Willamette meteorite was discovered near the border of Clackamas County, Oregon, in the autumn of 1902. It is remarkable for its very great size, its extreme dimensions as taken by Mr. Ward being as follows: Length, 10 ft. 3½ in.; breadth, 7 ft.; vertical height, 4 ft.; circumference of base, 25 ft. 4 in. It has a roughly conical form, with an oval base and dome-like summit. Its weight is estimated as being approximately 13½ tons. When the mass was found the cone-shaped portion was below, while the flat base was near the surface of the ground. The former, which

was obviously the front side in the progress of the meteorite though the air, shows in the first place a border area quite covered with the usual pittings; also a number of round well-defined bore-holes mostly near the lower border explained by the disappearance of cylindrical nodules of some sulphide as troilite; and, finally a series of deep open basins and broad channels of great size, which are regarded as owing their origin to the friction of the compressed air in the rapid passage of the meteorite. The base of the mass, 10 ft. × 7 ft. in dimensions, is also remarkable in another way, since the once continuous surface is now largely replaced by a labyrinth of basin-like cavities, some of them very large. These are believed to have been formed by the decomposition of the mass under the action of terrestrial agencies, chiefly water, as it lay for an unknown period with the side exposed. An etched surface of the iron shows the usual crystalline figures and assigns the meteorite a place in the group of octahedral irons. The analysis shows that the mass contains 8 per cent of nickel. The plates accompanying the paper give striking views of the remarkable features of this extraordinary mass. The ownership is at present the subject of litigation, so that the final disposition of the specimen is yet in doubt.

8. *British Tyroglyphidæ;* by Albert D. Michael. Volume I, 1901, pp. xiii+291; plates xix; Volume II, 1903, pp. vii+183; plates xxxix. London (The Ray Society).—Mr. Michael's ability as a student of Acarina was well demonstrated by his excellent monograph of the Oribatidae, published by the Ray Society in the 40th year of the Society (1883) and the 44th year (1887). His work upon the Tyroglyphidæ has, therefore, naturally attracted much attention from systematic workers in Arachnology. The first volume contains a full history of literature, an account of the classification, an extended description of the external and internal anatomy, and a chapter on the development of the immature stages. These chapters are followed by Part II, which contains systematic descriptions of the genera and species through the important and remarkable genus Glycyphagus. The second volume, beginning with the genus Chortoglyphus, completes the British fauna in this important family. There is added to this a list of the species foreign to Great Britain, and a bibliography. In his review of the classification of the Acarina, Mr. Michael, I think, does an inadvertent injustice to an American author, Mr. Nathan Banks, in his criticism of Banks's classification published in 1894. In the classification of the American writer little attempt was made at novelty in the characters employed. It was based upon the previous classifications of Canestrini and Trouessart, and, with slight modifications of these systems, consisted mainly in the erection of the principal groups into superfamilies with the "oidea" termination now generally adopted by systematic zoologists as indicative of superfamily rank. The points criticised by Michael in the classification are points originated by Trouessart and Canestrini and not by Banks.

The group Tyroglyphidæ is a most interesting and important one, comprising, as it does, species which occur commonly upon flour and meal, upon cheese, upon dried vegetables and drugs, and upon various plant growths, usually moribund but occasionally probably healthy. Interesting errors have occurred in previous observations upon mites of this family, and especially the striking blunder of Cross, who believed that he had created one species in his galvanic batteries. Another error has been the description of species brought up as living in the depths of the sea, when, in reality, the dredge had picked them off the surface of the water on which they were floating. Systematists in other groups in zoology will be interested to note that Mr. Michael seems not disposed to agree to the opinion of the committee of the International Zoological Congress, that the rule abolishing names founded upon larval forms should hold with the Acarina. Economic entomologists will be especially interested in Mr. Michael's conclusion that *Tyroglyphus phylloxeræ* Riley, a species which was supposed to feed on the grape vine phylloxera and which was imported from the United States into France to destroy this great pest, is a synonym of *T. mycophagus* Mégnin, does not feed on living insects, and already existed in France. The plates are very carefully done and are very beautiful. To the reader not previously informed concerning the anatomy of the species of Glycyphagus, for example, the representation of several species of this genus may be a revelation. L. O. HOWARD.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—The spring meeting of the National Academy was held at Washington, April 19 to 22.

Four new members were elected at this meeting: William Morris Davis, Harvard University; William Fogg Osgood, Harvard University; William T. Councilman, Harvard Medical School; John U. Nef, Professor of Chemistry, Chicago University.

The following foreign associates were also elected: Prof. Dr. Paul Ehrlich, Frankfurt; Prof. Dr. H. Rosenbusch, Heidelberg; Prof. Emil Fischer, Berlin; Sir William Ramsay, London; Sir William Huggins, London; Prof. Geo. H. Darwin, Cambridge; Prof. Hugo de Vries, Amsterdam; Prof. Ludwig Boltzmann, Vienna. The Draper gold medal was presented to Prof. George E. Hale of the Yerkes Observatory, for his researches in astrophysics.

The following is the list of papers presented:

E. L. NICHOLS and ERNEST MERRITT: On fluorescence spectra.
JOHN TROWBRIDGE: Spectra of gas at high temperatures.
THEODORE LYMAN: Short wave-lengths of light.
H. W. MORSE: Spectra produced by the Wehnelt interrupter.
GEORGE F. BARKER: Note on radio-activity and autoluminescence.
R. S. WOODWARD: A double suspension apparatus for determining the acceleration of gravity. The compressibility of the earth's mass required by the Laplacian law of density distribution.

HENRY L. ABBOT : The disposition of rainfall in the basin of the Chagres.
A. F. ZAHM : Surface friction of the air at speeds below 40 feet a second.
R. H. CHITTENDEN : Physiological economy in nutrition, with special reference to the minimal proteid requirement of the healthy man.
HENRY F. OSBORN : Recent paleontological discoveries by the American Museum exploring parties. Reclassification of the Reptilia.
W. D. MATTHEW : Position of the limbs in the Sauropoda.
HORATIO C. WOOD, JR. : A preliminary report upon Apocynum cannabinum.
ARTHUR T. HADLEY : Biographical memoir of James Hadley.
CHARLES L. JACKSON : Biographical memoir of Henry Barker Hill.
ALEXANDER GRAHAM BELL : The multi-nippled sheep of Beinn Bhreagh.
SIMON NEWCOMB : Application of new statistical methods to the question of the causes influencing sex.
C. S. PEIRCE : Note on the simplest possible branch of mathematics.

2. *Report of the Superintendent of the Coast and Geodetic Survey, showing the Progress of the Work from July 1, 1902 to June 30, 1903.* Pp. 1032, 4to, with numerous plates and sketch maps. Washington, 1903.—This volume contains the usual report (pp. 1–22) by the superintendent, O. H. Tittmannn, of the work accomplished by the Survey in the year ending June 30, 1903. Then follow seven Appendixes on details of field and of office operations; on precise leveling in the United States 1900–3; on triangulation southward along the ninety-eighth meridian in 1902; on magnetic observations from July 1, 1902 to June 30, 1903, etc.

3. *The 1900 Solar Eclipse Expedition of the Astrophysical Observatory of the Smithsonian Institution;* by S. P. LANGLEY, Director, aided by C. G. ABBOT. Pp. 26 with twenty-two plates. Washington, 1904.—The official report of the highly successful observations of the 1900 solar eclipse by the Smithsonian party at Wadesboro, N. C., is here presented. Of the accompanying plates the first gives a striking general view of the corona obtained from a 82-second exposure with the 11-foot focus camera; other beautiful plates give detailed illustrations of portions of the inner corona from 16-second exposure with the 135-foot focus camera, etc.

4. *Physique du Globe et Meteorologie;* par A. BERGET. Pp. 353; 128 figures and 14 colored double-page plates. Paris, 1903 (C. Naud).—This volume is the basis of an elementary course which the author is conducting at the Sorbonne, and appears at the suggestion of M. Velain. It is a serious and, on the whole, rather successful effort to collect all of the known facts that bear on meteorology. It is essentially non-mathematical; even elementary mathematical discussions being separated from the text proper by smaller type.

The book is divided into three parts, the first treating of terrestrial physics; 124 pages being devoted to the discussion of the size and position of the earth, its movements, determination of its density, universal gravitation, cosmogony, geodesy, the methods of determining g, with historical treatment, and terrestrial magnetism.

The second part deals with the physics of the ocean; its constitution, tides, the propagation of waves and currents are considered. The remainder of the book is devoted to the physics of

the atmosphere, under the topics: astronomical phenomena, constitution of atmosphere, actinometry, atmospheric pressure, winds, cyclones and anti-cyclones, centers of high pressures, periodical winds, general circulation, atmospheric perturbations, hygrometry, electrical phenomena, climate, forecasting.

The treatment is thoroughly French; still, the author acknowledges his regret that the observations in different parts of France (where they appear to differ in time by as much as four to five hours) are not made simultaneously and frequently as are those in this country. The slowness in the development of meteorology, he considers, is due rather to a lack of skill exercised in making observations than to any lack in the volume of records.

Despite the variety of subjects treated, the book is without an index. D. A. K.

5. *Ostwald's Klassiker der Exacten Wissenschaften.* Leipzig, (Wilhelm Engelmann).—The following volumes have been recently added to this important collection of reprints of classical scientific memoirs:

No 140. Experimental-Untersuchungen über Elektricität; von Michael Faraday. XX bis XXIII Reihe. Herausgegeben von A. J. von Oettingen. Pp. 174.

No. 141. Über die Bestimmung einer Elliptischen Bahn aus drei vollständigen Beobachtungen; von J. F. Encke. Über die Bestimmung der Bahn eines Himmelskörpers aus drei Beobachtungen von P. A. Hansen. Herausgegeben; von J. Bauschinger. Pp. 162.

No. 142. Fünf Abhandlungen über absolute elektrische Strom- und Widerstandsmessung, von Wilhelm Meyer und Rudolph Kohlrausch. Herausgegeben; von Friedrich Kohlrausch. Pp. 116.

6. *Studies in Heterogenesis;* by H. Charlton Bastian. Pp. ix + 354 + xxxvii, 19 pls. containing 815 reproductions from microphotographs. London, 1904 (Williams & Norgate.)—Heterogenesis as defined by Dr. Bastian is "the production from the substance of organisms or their germs of alien forms of life." Numerous instances are given to show transformation of the contents of vegetal cells to amœbæ and monads, of algæ to diatoms. The egg of the Hydatina can be transformed into a ciliated infusorian! The processes by which Dr. Bastian arrives at his startling conclusions will hardly stand the test of modern scientific research.

Obituary.

M. F. A. Fouqué, the distinguished French geologist, petrographer and mineralogist, died at Paris on March 7, in his seventy-sixth year.

M. Henri Perrotin, the eminent French astronomer, Director of the Observatory at Nice, died early in March at the age of fifty-eight years.

Professor Fredrik Adam Smitt, the well known Swedish geologist, died on February 19, in his sixty-fifth year.

Dr. James Hyatt, one of the pioneers in science in this country, died at Bangall, N. Y. on February 27, in his eighty-seventh year.

C. E. Beecher

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

CHARLES EMERSON BEECHER.

One of America's leading paleontologists, in the fullness of intellectual power, suddenly passed away on February 14, 1904, in the midst of his family and work. Few men were better prepared and more promising of great results for the next twenty years than Charles E. Beecher. "There is no doubt that in the death of Professor Beecher, not only has Yale sustained a serious loss and paleontology a severe blow, but the ranks of those capable of bringing to the study of fossils keen insight and a philosophical spirit of enquiry, guided by principles whose value can hardly be exaggerated, are diminished by one whom science could ill afford to lose, and to whom, humanly speaking, there should have remained many years of industry and fruitful research." (W. H. Dall, Science, March 18, 1904.)

Like most successful students of organic life, Beecher was a born naturalist. As a boy of twelve years he began to make a collection of recent shells and fossils, continuing to add to this for the next thirty years, when, in 1899, he presented Yale University, "unconditionally," with upwards of 100,000 fossils. In the field few excelled Beecher as a collector. When twenty years of age he published his first paper—a list of the land and fresh-water shells of Ann Arbor, Michigan. For the next eight years he published nothing, his second paper appearing in 1884, and in 1888, when he left Albany,

there were but twelve papers to his credit. Since that time, during the years spent at New Haven, he has written fifty-eight articles, making a total of seventy numbers in his bibliography. As a paleontologist he began by describing species and genera, but later he took almost no interest in this kind of work. Often he told the writer that he wished all our fossils were named. Of faunal and stratigraphic papers he has five, and of new species he described but thirty-six. He defined nine new genera and seven new orders. During the past fifteen years his mind was absorbed in working out the ontogenetic stages in fossil species and in tracing their genetic sequence through the geological formations. To Beecher we owe the first natural classification of the Brachiopoda and Trilobita, based on the law of recapitulation and on chronogenesis. He also gave a very philosophic account as to the origin and significance of spines in plants and animals. On these works his reputation in days to come will chiefly rest.

Beecher was not only a born naturalist but also had much mechanical ability. Nothing pleased him more than to free fossils from the surrounding matrix, and his unexcelled talent in this direction is shown in the preparations of *Triarthrus* and *Trinucleus* in the Yale University museum. More than 500 specimens have been prepared by him and this work has required peculiar skill, patience, ingenuity, and a great deal of time. Few can appreciate Beecher's remarkable talent in cleaning the adhering black shale from these small specimens, and it will be a long time before another will be found who can equal him in this respect. It is very unfortunate that he did not live to complete his studies on the trilobites, but he left all the better specimens completely worked out, and of most of these he had made photographs and drawings. His mechanical bent was also evidenced at his home, where he had a bench and a large kit of tools. Here his diversion consisted in making brass scrolls, shelves, and delicately carved boxes and chests. His preparations for the microscope, also, are of the best, and much time in his earlier years was spent in freeing and mounting the lingual dentition in small species of living gastropods. He likewise modeled and made a life-size restoration of the Devonian giant *Stylonurus.*

After Beecher's appointment as Curator of the geological collections at Yale, he also undertook to arrange, develop, and place on exhibition the large Marsh collection of vertebrates. His work in this connection, however, was chiefly directive, although he assisted considerably in the mechanical work of the large mounts of *Claosaurus annectens* and *Brontosaurus*. The life-like poses selected for these specimens are evidences of his artistic perception. The former he has described at length in the Transactions of the Connecticut Academy.

Charles Emerson Beecher, son of Moses and Emily D. Beecher, was born in Dunkirk, New York, October 9, 1856. Not long after this date, his parents removed to Warren, Pennsylvania, where he prepared for college at the High School, and was graduated from the University of Michigan, receiving the degree of B.S. in 1878. The ten succeeding years he served as an assistant to Professor James Hall, and in 1888 removed to New Haven to take charge of the collections of invertebrate fossils in the Peabody Museum. His career as a teacher of geology began in 1891 when for two years he took charge of Dana's classes at Yale, and in 1892 he was made Assistant Professor of Historical Geology in the Sheffield Scientific School, serving in this capacity until 1897 when he became Professor of Historical Geology and a member of the Governing Board in the Sheffield Scientific School. In 1899 he succeeded the late Professor Marsh as Curator of the geological collections, and was made a member of, and secretary to, the Board of Trustees of the Museum. In 1902 his title was changed to that of University Professor of Paleontology. He was eminently successful as a teacher both with undergraduates and with advanced students, his enthusiasm and kindliness of character arousing at once their interest and devotion.

Professor Chittenden, director of the Sheffield Scientific School, has said of Beecher: "Quiet and unassuming he never sought adulation, but where there was earnest work to be done, requiring skill, patience and good judgment, he would labor quietly and industriously, bringing to bear upon the problem such a measure of common sense and of thoughtfulness that confidence and respect for his conclusions were inevitable.

. . . . As a friend he was loyal and trustworthy, and his memory will always be cherished by his associates in the Sheffield Scientific School with a full realization of the great loss they have sustained in his removal from their midst, and with an equal realization of the great loss to the institution to which he was so ardently devoted and in the future of which he had such great confidence."

Beecher received the degree of Ph.D. from Yale in 1889, his thesis being a memoir on the Ordovician Brachiospongidæ. In 1899 he was elected a member of the National Academy of Sciences, a foreign correspondent of the Geological Society of London, and a fellow of the Geological Society of America. In 1900 he was elected President of the Connecticut Academy of Arts and Sciences, and filled this office for two years. He was also a member of the American Association of Conchologists, Geological Society of Washington, Boston Society of Natural History, and Malacological Society of London.

Beecher's first paleontologic paper was published by the Geological Survey of Pennsylvania in 1884, when he was twenty-eight years old. It treated of new genera and species of Phyllocarida from the Devonian, a group of rare Crustacea, most of which he had found about his home. He was always on the lookout for these rare fossils, and after securing many hundred additional specimens, he again returned to the subject, and in 1902, in a paper published by the Geological Society of London, embodied all that is known of the Upper Devonian Phyllocarida of Pennsylvania.

If, during the past ten years, Beecher's time had not been so much taken up with trilobites, he probably would have worked out a phylogenetic classification of the corals. In 1891 he published two important papers on paleozoic corals, one based on *Pleurodictyum lenticulare* and the other on *Michelinia convexa*. He concluded that poriferous corals begin with a simple cyathiform corallite, without mural pores, and with septa first appearing toward the end of this stage. These features "indicate a primitive, simple, and imperforate ancestry for the Perforata." The next stage is suggestive of *Aulopora*, and the final stage in *P. lenticulare* has at least seven mural pores open-

ing into the primary calyx. In regard to the mural pores, he concluded from a study of them in *Favosites*, *Striatopora*, *Pleurodictyum*, and *Michelinia*, that they "are ineffectual attempts at budding, resulting only in the perforation of the cell walls."

In his third paper on corals he states that a specimen of *Romingeria umbellifera* measuring 100×200^{mm} has approximately 1500 corallites on each zone, or 4500 on the three zones. In 85 per cent of individuals each corallite gives rise to twelve buds, so that if each of the 1500 corallites of the basal zone give rise to twelve buds, there should be on the third zone 253,500 corallites. However, as there are only 4500 in the specimen in the three zones, "this shows a suppression of 243,000 corallites on two zones."

Beecher's first turn from stratigraphic paloentology to pure paleo-biology and correlation had its origin in the brachiopods. While at Albany he became acquainted with Hyatt's principles, although it was not until he had been some years at New Haven that he fully appreciated their application to fossils. Hall had made large collections of the Silurian fossils at Waldron, Indiana. This collection contained many slabs, and, as much loose clay adhered to them, Beecher saved the washings and out of these he and Clarke obtained about 50,000 specimens of young brachiopods. Their results were published in 1889 in a well-illustrated paper entitled "Development of some Silurian Brachiopods." In summing up the developmental changes, they made the following very significant statement: "In nearly every species the inceptive state is represented by a shell having a subcircular outline, with valves of slight convexity. This phase usually disappears before the individual reaches a length of 1^{mm}, after which the specific characters are assumed." Widely differing species "are alike in form, contour, convexity, beaks, and cardinal area, and the only marked differences are to be found in the faint indications of plications, striæ, folds and sinuses."

From a study of the nature of the pedicle opening they concluded that the "phylogenetic development tended in two main channels—one leading through *Strophomena*, *Scenidium*, *Orthisina*, *Leptæna*, *Chonetes*, *Productus*, and *Strophalosia*, and the other in the direction of *Rhynchonella*, *Spirifer*,

Atrypa, *Retzia*, and *Terebratula*." It will be noticed that this arrangement of widely differing genera foreshadows two orders of brachiopods for which Beecher later proposed Neotremata and Telotremata.

My acquaintance with Beecher began in 1889, and at that time it was evident that the paper just referred to was being considered with a better understanding of what Hyatt's principles meant when applied to Brachiopoda. The very fact that nearly all the Waldron, Indiana, brachiopods began with smooth shells having a subcircular outline, led him to look for this early stage in other genera, but as no other young shells were at hand, he resorted to a study of the beaks in well-preserved examples of mature shells. During the fall of 1890 he spent nearly a week going through my collection, and with studies made on other collections he was able to announce in the spring of 1891 that he had seen the initial shell in fifteen families as recognized by Œhlert in Fischer's "Manuel de Conchyliologie," these being represented by forty genera.

At this time he made the important announcement "that all brachiopods, so far as studied by the writer, have a common form of embryonic shell, which may be termed the *protegulum*." The protegulum is the phylembryonic stage of Brachiopoda. A prototype preserving throughout its development the main features of the protegulum was at first supposed to exist in the Lower Cambrian *Paterina*, but as this proved to be identical in structure with *Iphidea*, the conclusion had to be abandoned. However, at maturity this genus is so closely related in general form with the protegulum, that we may hope at any time to find the prototype.

A study of the stages of growth in many brachiopods, from the Cambrian to the living forms, enabled Beecher to show that the old classifications based upon the presence or absence of hinge teeth, the nature of the intestinal canal, etc., were not expressive of genetic relationship. He demonstrated that on the basis of types of pedicle openings all brachiopods are naturally grouped into four orders, of which two are without and two possess hinge teeth. The most primitive order (*Lingula*, etc.) he named Atremata, and this gave rise directly to the Telotremata (*Rhynchonella*, *Terebratula*, etc.). The Neotremata (*Crania*, *Discina*, etc.) also originated in the Atremata,

and from the former descended the Protremata (*Strophomena*, *Productus*, etc.).

One of the clearest cases of parallelism between the ontogeny and phylogeny in a group of invertebrates was described by Beecher. Living species of the family Terebratellidæ have a very wide distribution, and he showed that the highest genera of the austral forms "pass through stages corellated with the adult structure in the genera *Gwynia*, *Cistella*, *Bourchardia*, *Megerlina*, *Magas*, *Magasella*, and *Terebratella*, and reach their final development in *Magellania*." In the forms having a boreal distribution the metamorphoses corellate "with adult structures of *Gwynia*, *Cistella*, *Platidia*, *Ismenia*, *Mühlfeldtia*, *Terebratalia*, and *Dallina*. The first two stages in both subfamilies are related in the same manner to *Gwynia* and *Cistella*. The subsequent stages are different except the last two, so that the *Magellania* structure is similar in all respects to the *Dallina* structure, and *Terebratella* is like *Terebratalia*. Therefore *Magellania* and *Terebratella* are respectively the exact morphological equivalents to, or are in exact parallelism with *Dallina* and *Terebratalia*.

"In each line of progression in the Terebratellidæ, the acceleration of the period of reproduction, by the influence of environment, threw off genera which did not go through the complete series of metamorphoses, but are otherwise fully adult, and even may show reversional tendencies due to old age; so that nearly every stage passed through by the higher genera has a fixed representative in a lower genus. Moreover, the lower genera are not merely equivalent to, or in exact parallelism with, the early stages of the higher, but they express a permanent type of structure, as far as these genera are concerned, and after reaching maturity do not show a tendency to attain higher phases of development, but thicken the shell and cardinal process, absorb the deltidial plates, and exhibit all the evidences of senility."

In 1893 there was discovered in the Utica formation near Rome, New York, a thin band not more than one-fourth of an inch thick, in which nearly all the fossils preserved (*Triarthrus* and *Trinucleus*) occur as pseudomorphs in iron pyrite, and retain antennæ and legs. Specimens of trilobites with legs had been known before in two specimens, and in four genera

the legs had been determined by slicing enrolled individuals. Antennæ, however, had not been clearly made out until 1893, when their presence was announced in the August number of this Journal. This discovery was of great value and promised much toward a better understanding of the ventral anatomy of trilobites and their systematic position among the Crustacea. This led to Beecher's visiting the locality in 1893 to take out several tons of the shale. Even as late as last fall he developed from this material specimens of *Trinucleus* showing the ventral appendages in the greatest detail. Since 1893 Beecher has published fifteen papers on the trilobites. Of these three are devoted to the larval stages, seven to the ventral anatomy, and five to classification and the systematic position of these forms.

The ventral anatomy is most completely known in *Triarthrus*, "an active creature" belonging to an ancient Cambrian family. Beecher showed that in this genus the entire series of thoracic legs are biramous, one of them setæ-bearing and used for swimming (expodite), and the other without setæ and used for crawling (endopodite). The limbs of the pygidium overlap each other, are much crowded, and are adapted for swimming or guiding the animal, although they may also have served as egg carriers. The individual segments "are considerably expanded transversely, thus making a paddle-like organ." The head has five pairs of appendages as follows: Anterior antennæ or uniramous antennules attached at the side of the hypostoma, followed by four pairs of biramous appendages closely resembling the thoracic legs. These are (1) posterior antennæ, (2) mandibles, (3 and 4) maxillæ. The ventral membrane of *Triarthrus* "is of extreme tenuity" and is an "uncalcified, chitinous, flexible pellicle, and thus was in strong contrast with the much thicker and calcified dorsal test."

The larval stages he studied in nine genera ranging from the Cambrian to the Lower Devonian. He concluded that "all the facts in the ontogeny of the trilobites point to one type of larval structure." This larva, not more than one millimeter in length, is "characteristic of all trilobites, and among different genera, varying only in features of secondary importance. This stage may therefore be called the *protaspis*." He found that Barrande's four orders of trilobite development are but stages of his first order, and that *Agnostus* is "neither

the phylo-typembryo nor the phylo-phylembryo, but is really the adult equivalent to an early segmented stage of the higher genera." Beecher divided the early stages of development in trilobites as follows: "Nauplius (Cephalon predominating, other parts not separated from it), Phylembryonic (Cephalon distinct, thorax nothing, pygidium distinct), Nepionic with as many stages as there are normal thoracic segments (Cephalon distinct, thorax incomplete, pygidium distinct), Neanic (Cephalon, thorax and pygidium all distinct and complete; growth incomplete), Ephebic (all parts complete and full size attained)."

The protaspis is homologous to the crustacean nauplius, which had "potentially five cephalic segments bearing appendages, which should therefore be taken as characteristic of a protonauplius. The nauplius is a modified crustacean larva. The protaspis more nearly represents the primitive ancestral larval form for the class, and approximates the protonauplius."

The basis for Beecher's classification of the trilobites is the application, for the first time, of the law of morphogenesis, or the recapitulation theory. He observed that in the first or unsegmented stage of the most primitive trilobites there are neither dorsal free cheeks nor eyes, but that in some of the later forms both the eyes and free cheeks have migrated to the anterior margin or may even have progressed a little posteriorly down the dorsal side of the protaspis. This led him to undertake a study of all trilobite genera, more than two hundred in number, and it was seen that these could be arranged in three groups on the basis of the nature and position of the free cheeks. In the most primitive order, or the Hypoparia, there are "free cheeks forming a continuous marginal ventral plate of the cephalon, and in some forms also extending over the dorsal side at the genal angles." In the Opisthoparia the dorsal "free cheeks include the genal angles, thus cutting off more or less of the pleura of the occipital segment;" while in the Proparia, or the last order to arise, "the pleura of the occipital segment extend the full width of the base of the cephalon, embracing the genal angles."

There is much diversity of opinion regarding the rank of trilobites in a classification of the Crustacea. Beecher regarded them as a sub-class and as equal in rank to the Entomostraca and Malacostraca. "In nearly every particular the trilobite is very primitive, and closely agrees with the theorétical crusta-

cean ancestor. Its affinities are with both the other sub-classes, especially their lower orders, but its position is not intermediate."

In 1892 Beecher became greatly interested in the significance of spines, accumulating data until 1898, when he presented his studies in a paper entitled "The origin and significance of spines." This paper Beecher regarded as his best and most philosophic work. In the opening paragraph he states "the presence of spines in various plants and animals is, at times, most obvious to all mankind, and not unnaturally they have come to be regarded almost wholly in the light of defensive weapons." "Their importance lies not in what they *are*, but in what they *represent*. They *are* simply prickles, thorns, spines, or horns; they *represent*, as will be shown, a stage of evolution, a degree of differentiation in the organism, a ratio of its adaptability to the environment, a result of selective forces, and a measure of vital power."

"In tracing the ontogeny of a spinose form, it has been found that each species at the beginning was plain and simple, and at some later period, spines were gradually developed according to a definite sequence of stages. Usually after the maturity of the organism, the spines reach their greatest perfection, and in old age, there is first an over-production or extravagant differentiation followed by a decline of spinous growth, and ending in extreme senility with their total absence."

He found that all kinds of spines in plants and animals can be arranged into eleven distinct categories. Further, that two generalizations result as follows: "That spinosity represents the limit of morphological variation, and second, it indicates the decline or paracme of vitality." "Finally it is evident that, after attaining the limit of spine differentiation, spinose organisms leave no descendants, and also that out of spinose types no new types are developed."

Beecher's standing among biologists and paleontologists was high; he was a leader among students of Brachiopoda and Trilobita. His paleontologic work at Yale was essentially of a biologic and philosophic character. He had the artist's gift, nearly all the drawings illustrating his various papers being made by himself and exhibiting a high order of merit. He

was a slow and very careful worker. Those who knew him well saw in him an enthusiast, but his exuberance was always held in check by his judicial qualities, which also made him an excellent counselor. He was orderly in his work, and, as he had the "museum instinct" well developed, he made one of the best of museum curators.

In 1894, Beecher married Mary Salome Galligan of Warren, Pennsylvania, who, with two daughters, survives him. He died very suddenly of heart disease at his home, shortly after one o'clock on Sunday afternoon, February 14. Up to about eleven o'clock of the same day, he was in his usual health. He lies in Grove Street Cemetery, in the shadow of the Sheffield Scientific School.

CHARLES SCHUCHERT.

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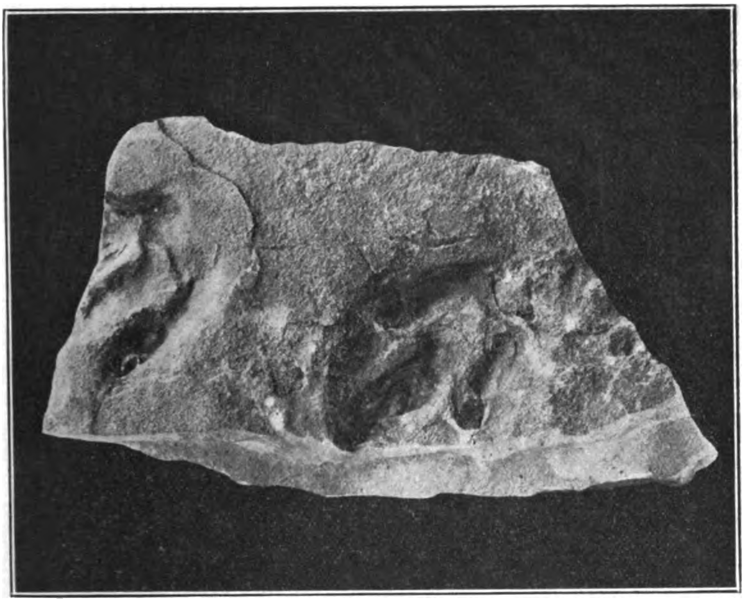
ART. XXXIX.—*Dinosaur Footprints from Arizona*; by E. S. RIGGS.

A SLAB of sandstone bearing dinosaur footprints, recently received at the Field Columbian Museum, is of interest in marking a new locality for these well-known fossils. The tracks were found in the bluffs overlooking the Colorado River,



Dinosaur tracks one-fourth natural size.

near Lees' Ferry in Northern Arizona. Mr. F. V. Kearn, the collector, reports that there were six impressions in all, but he succeeded in preserving only two. The matrix is a sharp, fine-grained sandstone of a bluff color when freshly broken, but weathering to a dark reddish brown. Data as to the geological horizon are wanting, but it may be assumed that the specimen is of Triassic age.

The impressions are evidently made by the hind feet of a tridactyl animal similar in structure to those of *Allosaurus* Marsh, but considerably smaller. The tracks preserved are but a few inches apart and were apparently made in wet sand. That of the right foot is barely its own length in advance of the left and is separated by a similar distance laterally. It may

therefore be inferred that the tracks were made by a bipedal animal walking leisurely along a sandy beach.

In outline the tracks are almost symmetrical to a line passed through the imprint of the middle digit. The axis of the foot is deflected but little from the line of stride. The middle digit was evidently strongest and bore more than an equal share of the animal's weight. The two lateral digits appear to have been equally functional and, like the middle one, were armed with claws. The inferior surface of the foot was provided with pads similar to those of struthious birds. In digit II the weight was borne upon the first and second phalanges, in digit III upon the second and third, while in digit IV the second, third and fourth were evidently brought to the ground. In addition to this there is an imprint of a heel-like pad which was borne by the distal ends of the metatarsals.

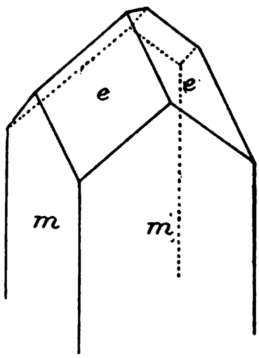
Measurements are as follows:

	M
Length over all	·128
Breadth	·103
Length of lateral digits from heel	·079
Angle between digits II and III	35°
" " III " IV	30°

Art. XL.—*A New Habit for Chalcopyrite*; by R. W. Richards.

A specimen of chalcopyrite collected in Somerville, Massachusetts, by Prof. A. E. Dolbear, of Tufts College, some years ago, shows apparently a new and simple habit for the species. The specimen was found in a vein of rusty quartz in the quarry between Broadway and Holland Streets, near Clarendon Hill. The rock of the quarry is the so-called Cambridge or Somerville Slate, referred by some geologists to the Carboniferous, by others to the Lower Cambrian. This rock is a clay-slate cut by many diabase dikes, which in turn are cut by numerous veins carrying a great variety of minerals, among which quartz, calcite, albite, prehnite, babingtonite, erythrite, chlorite and oxides of titanium, recently discovered by Prof. Charles Palache, of Harvard University, may be mentioned.

The crystallization of chalcopyrite is tetragonal, and a sphenoidal habit usually predominates. Prof. S. L. Penfield, in his paper in this Journal on crystals from Chester Co., Pa. (vol. xl, 207, 1890), figured specimens showing prismatic and pyramidal planes, and others showing sphenoid and scalenohedral faces, which he suggests may represent a prism and a second order pyramid distorted by oscillatory combination with the positive sphenoid. The indices he assumes for the distorted forms agree with the forms found on the crystal described in this note.



The Somerville specimen is shown in the cut and possesses only two forms, a prism *m* and a second-order pyramid *e*. These have the indices 110 and 101, respectively, and present the identical faces figured by Prof. Penfield, in a twin crystal (l. c. fig. 8, p. 210). The rough character of the Somerville crystal permitted only contact measurements and the best readings were selected by choice. The angles giving the most satisfactory set of readings are those around the coign *m* to *e*, *e* to *e*, and *e* to *m*. These angles are nearly equal and were found by measurement to be about 60°. This satisfies the relation that should obtain between the planes of the prism and those of the second-order pyramid,

e to *e*,	59° 30·5′
e to *m*,	63° 46·1′.

In Hintze's Handbuch der Mineralogie, sixteen cases are noted of the occurrence of the form *e*, and only seven of *m*. With the exception of one or two cases, either one or the other or both forms are subordinate. The Somerville crystal seems novel in showing these forms predominant and, perhaps, excepting the sphenoid, represents the simplest form of the crystallized mineral.

It is interesting to note that this form differs very slightly from the isometric dodecahedron. This similarity is accounted for by the axial ratio of the mineral, 1 : 0·98525. The resemblance of the crystal to the dodecahedron is well brought out by comparing it with a model of the same. In the drawing and in the crystal itself, the illusion is destroyed by the downward extension of the prism plane.

The crystal is unusually large for the species, having an average diameter of four centimeters. The largest of the Chester County crystals had diameters of a centimeter. Lacroix mentions large crystals from Oued Allelah of Algeria, Africa, having diameters of eight millimeters. The rather indistinct sphenoids from Ellenville, N. Y., have about the same dimensions as the Somerville crystal.

Credit is due to Prof. Palache for assistance in the examination of the specimen and suggestions in regard to its importance.

Tufts College, Massachusetts, 1904.

Art. XLI.—*Molecular Weights of Liquids, with a few Words about Association;* by C. L. Speyers.

For some years past, evidence has been advanced* to show that

$$\frac{n}{N}=\frac{p-p'}{p'} \tag{1}$$

agrees with experiment far better than

$$\frac{n}{N}=l\frac{p}{p'} \tag{2}$$

does. While (1) is as true for concentrated solutions as for dilute ones, (2) fails both in theory and in fact for concentrated solutions, though of course good for dilute ones.

A theoretical foundation was sought for (1) in the notion that a volatile liquid produces those molecules which pass off as vapor *in the body of the liquid* instead of merely on the surface, a notion which J. Traube† is advancing as one of the results of his study of critical phenomena, and that the vapor tension of a liquid is the result of such differentiation in the liquid.

Moreover, on combining (1) with the second law of thermodynamics we get equations for the molecular rise in boiling point and depression in freezing point, for the molecular heat of vaporization and of freezing, and all these independently of the osmotic theory.

Equation (1) has also been advanced tentatively by S. Young and E. C. Fortey‡ but with some reservations in regard to changes in density. The new mixtures that they used were ethyl propionate with ethyl acetate, toluene with ethyl benzene, n hexane with n octane and toluene with benzene. Slight differences were found between observed pressures and those calculated by (1), but no account was taken of a possible association of the vapor of the solvent and so these differences lose something of their significance. In their paper, the writers correct a mistake made by me. They point out that mixtures of non-associated liquids may have minimum boiling points. I stated they could not, and in this respect was wrong, having overlooked the fact that $\Delta p_2/\Delta t$ could be smaller than $\Delta p_1/\Delta t$ at one temperature while greater at another, both temperatures lying within the range of boiling points of the mixtures.

* Journ. Phys. Chem., ii, 347, 362 (1898); Journ. Am. Chem. Soc., xxi, 282 (1899); this Journal, ix, 341 (1900); xiii, 213 (1902).

† Drude's Ann., viii, 267 (1902).

‡ Journ. Lond. Chem. Soc., lxxxiii, 45, 68 (1903).

A word now in regard to association.

Let us consider water. Its density in the gaseous state leads to a formula for its molecule of H_2O. When metals react with it, we get hydroxides and oxides of the general formula $M(OH)_x$ and M_xO_y. In all chemical respects water behaves as if it had the formula H_2O, two replaceable hydrogen atoms and one replaceable oxygen atom, no more, no less. This formula, therefore, has a chemical, a scientific, significance. It states that in chemical reactions two atoms of hydrogen and one of oxygen go together. But in some physical relations, in those relations which involve water as a liquid and in which it stays a liquid, that formula does not account for things. Water is now not so active as corresponds to H_2O. To bring its activity up to what experience has determined to be the normal, the standard, activity, we must take two, three, or more times the mass corresponding to H_2O. We are, therefore, tempted to say water is associated, and to write $(H_2O)_a$ where a runs up to three or four for water and reaches much higher figures with some other liquids. But in so doing we use an unsuitable formula, because the liquid does not behave chemically as this expression suggests. So it is very undesirable to speak of associated molecules. More definite, and far more in accord with what we know, to say that the activity of the water is depressed below the normal than to say its molecule has been associated. The weak notion of associated molecule is replaced by the virile notion of activity. We shall call the above quantity denoted by a, the activity factor. *The activity factor* a *denotes the number of normal grammolecules which must be taken to give an activity equal to the normal, or standard, activity, the standard activity being determined by experience.* We are not to consider a as constant for any liquid but to vary with the conditions as well as with the liquid, and so the objection made by Young and Fortey* that (1) gave values for n which meant $a>1$ in certain mixtures of liquids for which in the pure state $a = 1$ is not valid.

The increased activity beyond the normal, which means $a<1$, called electrolytic dissociation or ionization, is another matter. There are regularities here which enable us to cast the processes into chemical equations. This we cannot do when $a>1$. When $a<1$ we find a chemical activity beyond the normal, so when $a>1$ we may by analogy look for a depressed chemical activity. This idea has not yet been put to the test.

Consider two volatile liquids, 1 and 2, not miscible in all proportions within certain limits of temperature and without chemical action the one upon the other. Let n_1, n_2, denote the

* l. c., 46.

number of grammolecules of each liquid when considered as solute; N_1, N_2, the number of grammolecules of the same liquids when considered as solvent, in computing which the ordinary molecular weight in the vapor state is to be used; p_1, p_2, the vapor tensions of the pure liquids; p_1', p_2', p_1'', p_2'', the vapor tensions of the same liquids in the solutions. Here and elsewhere the two coexisting solutions or phases are distinguished by $'$ and $''$.

At some fixed temperature let us add liquid 1 to a fixed quantity of 2. We have for the two components

$$\frac{n_1'}{N_2'} = \frac{p_2 - p_2'}{p_2'}\,;\quad \frac{n_2'}{N_1'} = \frac{p_1 - p_1'}{p_1}$$

which hold until the phase disappears entirely. When, on continued addition of 1, a second phase appears, we have the additional two equations

$$\frac{n_1''}{N_2''} = \frac{p_2 - p_2''}{p_2''}\,;\quad \frac{n_2''}{N_1''} = \frac{p_1 - p_1''}{p_1''}.$$

Since the phases are in equilibrium, $p_2' = p_2''$, $p_1' = p_1''$, and so

$$\frac{n_1'}{N_2'} = \frac{n_1''}{N_2''}\,;\quad \frac{n_2'}{N_1'} = \frac{n_2''}{N_1''}$$

The proportion of 1 to 2 is different in each phase, wherefore the activity factor, a, for each liquid must be different in each phase. Moreover, the quantity of 1 in 2 being greater in the second phase than in the first, the activity factor, a, is greater in the second phase than in the first, while $a_2' > a_2''$. A jump then in the mutual effects of two liquids, the one upon the other, accompanies the formation of two liquid phases, a jump in the effect of 1 upon 2 being balanced by the jump in the effect of 2 upon 1.

Following custom, we call that temperature above which two liquids dissolve in each other in all proportions, the critical temperature of solution, or for shortness just critical temperature. The composition belonging to the critical temperature we call critical composition and a solution of such composition a critical solution.

Let us start above the critical temperature with a solution of critical composition and with liquid 1 as solute, 2 as solvent, and cool the solution. As we pass down through the critical temperature, the homogeneous liquid separates into two phases, and as the change due to lowering the temperature is continuous, at a temperature infinitesimally below the critical temperature, the compositions of the two phases are only infinitesimally

different, and so their volumes, within an infinitesimal difference, are each one half the original volume, as has been shown by Konowalow.* As we pass on downwards below the critical temperature, the compositions of the two phases diverge, the divergence sometimes increasing indefinitely, sometimes diminishing at lower temperatures with promise of forming later on a homogeneous liquid with a second set of critical quantities.†

Let a_1 be the activity factor of liquid 1, m_1 its normal molecular weight, w_1 its mass in the phase under consideration. Let $t°$ be below the critical value. From 1 we get

$$a_1' = \frac{w_1'}{m_1 N_2'} \cdot \frac{p_2'}{p_2 - p_2'} \text{ and } a_1'' = \frac{w_1''}{m_1 N_2''} \cdot \frac{p_2''}{p_2 - p_2''}. \quad (3)$$

Since two phases are present, w_1' and N_2' as well as p are variable with t and so

$$\frac{da_1'}{dt} = \frac{1}{p_2 - p_2'} \cdot \frac{1}{m_1 N_2'} \left[\frac{w_1'}{p_2 - p_2'} \frac{p_2 dp_2' - p_2' dp_2}{dt} + \frac{p_2'}{N_2'} \frac{N_2' dw_1' - w_1' dN_2'}{dt} \right], \quad (4)$$

where dp_2'/dt is the differential coefficient of the vapor tension of the solution in the immediate neighborhood of the value p_2'; dp_2/dt, that of the pure solvent in the immediate neighborhood of the value p_2. With the exception of

$$\frac{p_2 dp_2' - p_2' dp_2}{dt} \text{ and } \frac{N_2' dw_1' - w_1' dN_2'}{dt}$$

the signs of all the quantities are positive. For dilute solutions we shall put dp_2'/dt from the solution, approximately equal to dp_2'/dt from the pure solvent. That is, we shall assume that dp_2'/dt from the dilute solution is quite close to what we should get were we to differentiate the vapor tension from the pure solvent in the immediate neighborhood of the numerical value p_2'. We do this because we find that in dilute solutions, while the vapor tension curve of the solvent is depressed numerically it is not altered in character, and because we seek the sign of the first quantity rather than its numerical value. With this understanding we find

$$\frac{p_2 dp_2' - p_2' dp_2}{dt} > 0$$

for water, methyl alcohol, i butyl alcohol, amyl alcohol, i amyl alcohol, i butyric acid, carbon disulphide, benzene, and chlorbenzene, and probably for all dilute solutions. Its numerical

* Drude's Ann., x, 360 (1902).
† Ostwald, Lehrb. ii, 670 (1902).

value is not large and does not seem to change rapidly. The other quantity we find is positive when $dw_1'/dt > 0$, for then by the nature of the case $dN_2'/dt < 0$, and negative when $dw_1'dt < 0$ for then $dN_2'/dt > 0$. Since $w_1' + w_1'' = w_1$ a constant, we have both cases so long as the two coexistant phases are present. For the more dilute phase with respect to 1 $dw_1'/dt > 0$, for the more concentrated phase $dw_1''/dt < 0$. For this one we write similarly to (4)

$$\frac{da_1''}{dt} = \frac{1}{p_2 - p_2''} \cdot \frac{1}{m_1 N_2''} \left[\frac{w_1''}{p_2 - p_2''} \cdot \frac{p_2 dp_2'' - p_2'' dp_2}{dt} + \frac{p_2''}{N_2''} \cdot \frac{N_2'' dw_1'' - w_1'' dN_2''}{dt} \right]. \quad (5)$$

From 1,

$$\frac{w_1''}{p_2 - p_2''} = m_1 \frac{N_2''}{p_2''}$$

which substituted in (5) gives for the bracketed part

$$m_1 \frac{N_2''}{p_2''} \left[\frac{p_2 dp_2'' - p_2'' dp_2}{dt} + \left(\frac{p_2''}{N_2''} \right)^2 \cdot \frac{1}{m_1} \cdot \frac{N_2'' dw_1'' - w_1'' dN_2''}{dt} \right]$$

The solution now being concentrated, we cannot predict much about the first term from a study of the vapor tension of the pure solvent. I think, however, we may assume that the numerical value of this term will not change rapidly compared with the other term. The second term changes rapidly because it is the arithmetic sum of two quantities, not the difference, and because it has in addition a factor which is the square of a fraction whose numerator and denominator both increase as t increases. Consequently, for quite a wide range in concentration we may look for a negative value for the quantity in brackets and therefore expect

$$\frac{da_1''}{dt} < 0 \quad (6)$$

while for the less concentrated solution

$$\frac{da'_1}{dt} > 0 \quad (7)$$

At the critical temperature, dw_1'/dt, dw_1''/dt, dN_2'/dt, dN_2''/dt all reduce to zero, and so from (4) and (5),

$$\frac{da_1'}{dt} = \frac{da_1''}{dt} = \frac{da}{dt} = \frac{w_1}{m_1 N_2} \cdot \frac{1}{(p_2 - p'_2)^2} \cdot \frac{p_2 dp_2' - p_2' dp_2}{dt}. \quad (8)$$

The solutions being concentrated we cannot predict at all concerning the sign of da/dt from the vapor tension curve according to temperature of the pure solvent, and the data at hand for the vapor tensions of the solutions are limited to a few

cases to be considered after we remark that a set of equations exactly similar to (3), (4), (5), (6), (7) and (8), hold for liquid 2, the two sets of equations being connected by the relations

$$w_1' + m_1 N_1'' = w_1$$
$$w_2'' + m_2 N_2' = w_2.$$

The cases in question are mixtures of anilin with amylene (trimethyl ethylene), and nitrobenzene with methyl iodid, with amylene, with ether, and with pentane, all investigated by Konowalow.* Only the first and last however gave coexistent phases. The others were above their critical temperatures. The highest temperature of the anilin mixture being 25·1° only the amylene was supposed to have an appreciable vapor tension and we are limited to the activity factor of the anilin only. For a similar reason we can find the activity factor of the nitrobenzene only, the temperature of the mixtures containing it being 18·1°.

1

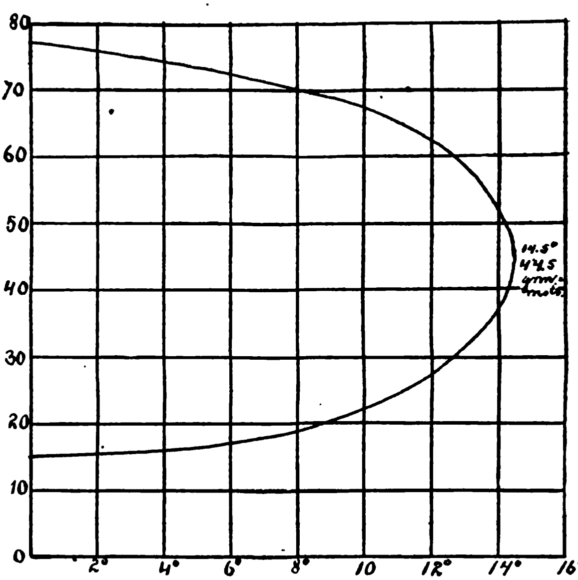


Figure 1 shows the compositions of the two coexistent phases for the anilin mixture from the critical temperature 14·5° down. The critical composition is 44·5 per cent grammolecules of anilin.

The following table contains the data necessary for finding the activity factor of the anilin. In it $t°$ is the temperature, p

* l. c.

the vapor tension of the pure amylene at $t°$, p' the vapor tension of the amylene from the solution, n the per cent grammolecules of anilin in calculating which the normal molecular weight of 93 is used, and a the activity factor computed according to (3) using 70 as the molecular weight of amylene. Should the vapor density of amylene be other than what corresponds to 70, the value for a would have to be correspondingly changed.

$t = 0°$ $p = 180·6$mmHg

n	p'	a
10·9	168·9	1·8
[15·0]	164·8	1·8
[77·5]	"	36
81·5	162	38

$t = 14·1°$ $p = 331·0$mmHg

n	p'	a
7·5	315·0	1·6
20	308·3	3·1
25·3	303·0	3·7
31·1	303·2	4·9
[37·0]		
42·2	301·8	7·5
45·5	302·0	8·7
50·7	302·6	11
[51·0]		
59 8	303·1	16
65·3	301·0	19
75	291·6	22
80	273·0	19

$t = 8·1°$ $p = 257·8$mmHg

n	p'	a
10.9	241·5	1.8
[19·0]	238·1	2·8
[69·0]	"	27
75	234	29

$t = 18·1°$ $p = 391$mmHg

n	p'	a
24·2	354·9	3·1
35·1	352·2	4·9
49	351	8·4
69·9	342·7	16
73·1	336·5	17
82	303·1	16

$t = 25·1°$ $p = 498·9$mmHg

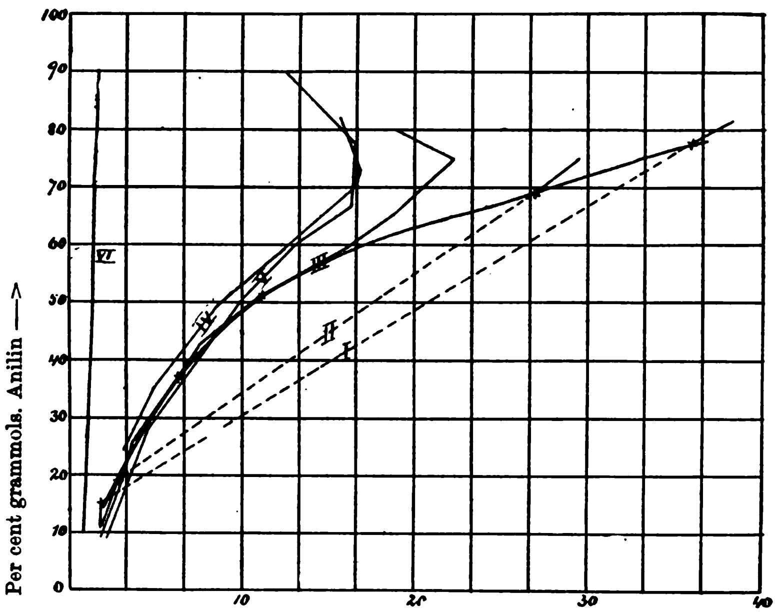
n	p'	a
9.2	476·6	2·2
28·2	458·9	4·5
49·2	453·8	9·7
50·1	453·1	9·9
59·8	447·9	13
66·7	444·2	16
77·7	411·8	16
89·7	295·4	13

From figure 1 we see that at 0° the two layers have the composition of 15·0 and 77·5 per cent grammolecules. These values have been enclosed in [ ], Konowalow giving the vapor tension but not the corresponding compositions. Similarly for the phases at 8·1°. Two phases should have formed at 14·1° but they do not seem to have become visible.

The values for a have been plotted in figure 2. The crosses × mark the compositions of the coexistent phases. Plot 1 corresponds to 0°. We observe that in the phase dilute with respect to anilin, the activity factor is small, only about 2, that is, the anilin is comparatively active, but when the per cent of anilin is large, the activity factor is very large up to about 36 so that now the anilin is very inert. At 0° then we may expect to find dilute solutions of anilin in amylene more active

chemically with respect to the anilin than concentrated ones in amylene. Similarly for plot II at 8·1° and for plot III at 14·1° up to about 75 per cent grammolecules of anilin. From that concentration on and at a temperature around and beyond the critical temperature, the activity factor begins to diminish again, indicating that pure anilin has a greater activity than when in concentrated solutions in amylene.

2



Activity factor a ——>
I at 0°, II at 8·1°, III at 14·1°, IV at 18·1°, V at 25·1°.
VI. In $(C_2H_5)_2O$ at 16·2°.

At low concentrations, up to 15 per cent grammolecules of anilin, a increases with the temperature, in accordance with what is stated after equation 4; but at high concentrations, so long as two coexistent phases are present, the reverse is the case, a diminishes as the temperature increases, which is in accordance with what follows after 5. When the temperature rises to 18·1° and the two coexistent phases disappear we find a increasing with the temperature so that in this concentrated solution,

$$\frac{p_2 dp_2' - p_2' dp_2}{dt} > 0$$

just as it would be for pure amylene.

The parabola-like curve shows how a changes with the temperature for pairs of coexistent phases. The dotted lines of I and II connect the coexistent phases. The two ×'s of III are not connected by a dotted line, because the values of the intermediate compositions and pressures are given by Konowalow. He points out that at the temperature to which this curve belongs, which temperature is very close to the critical one, p' varies very slightly with the composition for a range between 25 and 60 per cent grammolecules of anilin, whereas, according to figure 1, this should only be so between the limits of 37 and 51 per cent. We account for this quite readily, by the increasing value of a. Plot VI has been taken from a previous article.*

The following table contains the other data from Konowalow.

Nitrobenzene in methyl iodid.
$t = 18{\cdot}1°$ $p = 310{\cdot}7$mmHg

n	p'	a
19·7	260·5	1·3
40	210·7	1·4
50	185·4	1·5
66·6	137·1	1·6
82	79·5	1·6

Nitrobenzene in ether
$t = 18{\cdot}1°$ $p = 416$mmHg

n	p'	a
16	359	1·2
40·3	294·6	1·6
50·9	261·6	1·8
59·1	232·3	1·8
63·9	215·7	1·9
66·6	203·5	1·9
75	166·3	2·0
76	160·9	2·0
86·6	98·7	2·0
92·5	59·5	2·1

Nitrobenzene in amylene.
$t = 18{\cdot}1°$ $p = 391$mmHg

n	p'	a
16·5	351·2	1·7
32·3	332·9	2·7
41·6	323·7	3·3
59·9	294·8	4·6
66·6	263·8	4·1
78·8	207·9	4·2

Nitrobenzene in pentane.
$t = 18{\cdot}1°$ $p = 536{\cdot}3$mmHg

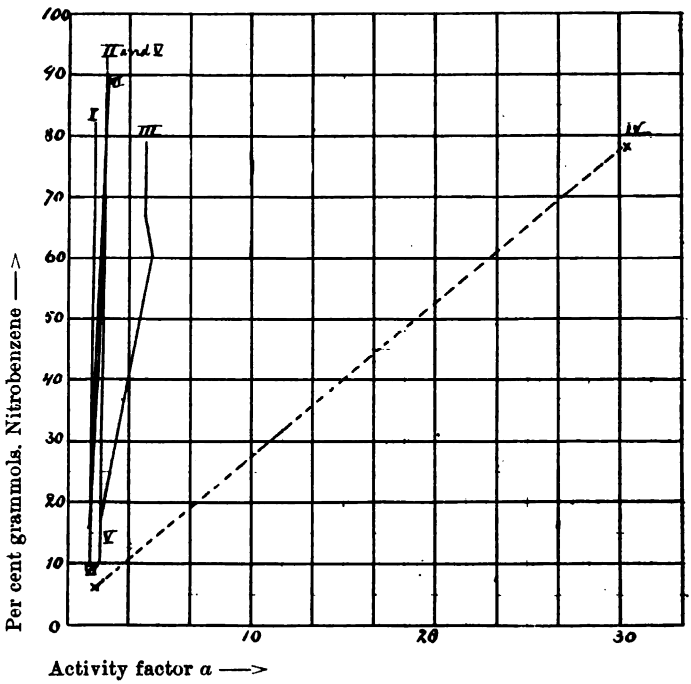
n	p'	a
5·9	514·3	1·5
two layers	504·0	
78·2	479·6	30

These data have been plotted in figure 3. The activity factor of nitrobenzene is pretty constant in methyl iodid and in ether, in amylene it increases considerably as the nitrobenzene increases, while in pentane the increase is 20 times what it was at the beginning. In this case, however, we have two coexistent phases. Unfortunately, the compositions of the coexistent phases are not given, only one composition before the coexistent phases have formed and one after the coexistent

* Journ. Phys. Chem., ii, 347 (1898).

phases have disappeared. The extremities of the broken line of IV mark the compositions of these solutions. I have added plots V and VI taken from an earlier article.* They fit in

3



I. In CH_3I. II. In $(C_2H_5)_2O$. III. In $(CH_3)_2C:CH(CH_3)$.
IV. In C_5H_{12}. $t^\circ = 18{\cdot}1^\circ$.
V. In CCl_4 $t^\circ = 34.8$. VI. In $(C_2H_5)_2O$ $t = 16.2^\circ$.

very well with these of Konowalow and together with VI of figure 2 show how characteristic of two coexistent phases the big jump in the activity factor is.

* l. c.

December 11, 1903.

ART. XLII.—*The Relation of Mass Action and Physical Affinity to Toxicity, with incidental discussion as to how far electrolytic dissociation may be involved;* by J. B. DANDENO.

MASS action, as a principle underlying chemical phenomena, is comparatively well established. The law may be briefly stated, that when any substance in a dissolved state enters into a chemical reaction, the amount of the action is proportional to the active mass of the substance. By mass of substance in solution, or molecular concentration, is meant the number—not actual but relative—of molecules per unit of volume. It may be expressed as so many gram-ions per liter of solution. An illustration of mass action is here given. When potassium nitrate and sulphuric acid are mixed in solution, a reaction, depending upon the mass of each in solution, takes place. Thus, if the acid be in excess, the resulting products are potassium bisulphate ($KHSO_4$) and nitric acid; but if a large excess of nitric acid be added to potassium bisulphate, the resulting products are H_2SO_4 and KNO_3. Such phenomena, though common enough in chemistry, are not well understood.

In this paper an effort is made to set forth one point of view from the physiological side. The radicles of some seedlings are used as the physiological reagent, and a few common solutions as the chemical; and silica to represent a possible physical agent.

By physical affinity is here meant the force of attraction, without chemical change, that substances may have for one another in solution. As will be shown in some of the experiments described in this paper, there is a very considerable amount of such attraction. It has been pointed out* that, with certain toxic solutions, the toxicity was much reduced when non-chemical† substances were present. But just to what extent such non-chemical substances have to do with the well-being of plants, little is at present definitely known. From this it is not to be inferred that such effects are the only effects which may result from the presence of non-chemical substances. It is this action alone,—this hindrance to the chemical action (which would take place if the non-chemical substance were not present)—which is here considered.

The importance of this is at once apparent, when one considers that the great mass of soil particles are non-chemical in their

* Dandeno, Trans. Can. Inst., vii, p. 315.

† By non-chemical substances is here meant those substances which do not react chemically in the experiment in question, and which are not soluble in the liquid used.

nature. The question of fertilizers—one of the most important to the farmer—is essentially a part of this question. For, if the particles of soil can mechanically hold substances in solution, then there will always be a certain amount in the soil which is not available to the roots of the plants. Moreover, roots will be able to withstand a greater amount of poisonous substance in the soil than they could if immersed in a liquid. There are numerous suggestions which may arise along this line, but the discussion in this paper is confined to two phases of the aspect,—(1) that of the inhibitory effects produced by pure sand upon toxic solutions, and (2) that of the relative effects, in the same regard, of fine and of coarse particles.

Considerable has been done within the last eight or ten years towards determining at what concentration of solution certain seedlings will survive, when the radicle is immersed in the solution for a given period of time. Kahlenberg and True,* 1896, record a large number of experiments made with *Lipinus albus*, and deduced certain results, some of which are quite probably unwarranted. Their general method of preparing solutions, a departure from the percentage method, is to be commended, though some confusion in regard to naming of solutions, and other errors of chemical formulæ, make it necessary to be cautious about accepting their results. Heald,† in the same connection, worked with seedlings of *Zea mais*, *Pisum sativum* and *Cucurbita*, but unfortunately confused matters somewhat in the same manner, so that one cannot reconcile his table summarizing results, with the individual tables. For example, on page 152, Heald gives the limit which for corn, just allowed growth as 1/102400 *eq.*, $CuSO_4$; while on page 140, same paper, he records for the same seedling a growth of 16·5 and 7^{mm} (for two successive days) in a solution of $CuSO_4$ 1/102400 *mol.* It seems a pity that more care was not taken in this regard. Stevens‡ worked with spores of a few fungi; and Loew§ gave results of experiments made with seedlings of indian corn.

True and Gies‖ worked with mixed solutions and this work bears somewhat upon the line of thought followed through a part of this paper. True¶ recorded the results of a large number of experiments with *Lupinus albus* along a similar line to that pursued by Kahlenberg and True. True and Hunkel** used certain of the phenols in a similar connection.

Moreover, the same problem has been touched upon from another point of view. O. Loew†† discussed the question of

* Bot. Gaz., xxii, 1896.
† Bot. Gaz., xxii, 1896.
‡ Bot. Gaz., xxvi, 337, 1898.
§ Science, Sept. 4, 1903, p. 304.
‖ Bull. Torr. Bot. Club, xxx, 390, 1903.
¶ This Journal (4), ix, p. 184, 1900.
** Bot. Cent., lxxvi, p. 9.
†† U. S. Dep. Ag., Bull. 18, 1899.

the function of certain of the mineral salts in the soil. Plowman* dealt with the question from the standpoint of electricity and magnetism, using plants growing in flowerpots. He concluded that ionization of the soil bore directly upon growth of plants. Cameron† deals with the same question mainly from the point of view of soils and crops. Clark‡ pursued a line of work similar to that of Stevens.

It is not the intention to give a complete historical bibliography of the subject, but rather to mention some of the more prominent work done directly along this line in order that correlation of data may be available. Due acknowledgment will be made of the work of each in its proper relation to this discussion.

The aim of most of those authors seems to have been to determine, for certain solutions, the concentration at which organs or organisms would just live, or just not live. Nothing apparently is said as to whether quantity of solution had anything to do with the life of the organism. Nor is anything said of the question as to whether the shape of the vessel, or the presence of foreign non-chemical bodies might have any influence upon the action of the substance in solution. The quantity of solution used was apparently considered of little importance by some of those who made experiments along this line, for little or no mention is made of quantity. Cameron (Bull. 71) and Loew (l. c.), however, are clear on this point.

The method of preparing solutions was in strict accord with the plan of chemical equivalents, that is to say, the solutions were so prepared and named that n stands for a gram-equivalent per liter of solution in each and every case. The number in the denominator of the fraction whose numerator is n, denotes the concentration of the solution under consideration. Where the acids or salts are monobasic, the gram-molecule is the same as the gram-equivalent; where the acid or salt is dibasic, then one-half the molecular weight to a liter is the gram-equivalent. It is not necessary to mention acids or salts of other basicity, as the two mentioned are the only kinds used in the experiments here described. In the case of the so-called acid salt ($NaHCO_3$), one-half the molecular weight in grams dissolved to a liter is the gram-equivalent per liter solution,—exactly similar in concentration to that of the carbonate (Na_2CO_3). This may seem unduly explicit on this

* This Journal (4), xiv, p. 129, Aug., 1902.

† (*a*) U. S. Dep. Ag., Bur. of Soils, Bull. 22, 1903.
(*b*) Jour. Phys. Chem., viii, 1, Jan., 1904.
(*c*) Bull. 71, U. S. Dep. Ag. This contains a particularly valuable discussion of the matter, Kearney being associated with Cameron in the work.

‡ Bot. Gaz., xxviii, p. 409.

point, but it is necessary to be so, considering some work which has been done along a similar line. For example, True* states, referring to H_2SO_4: "And since it splits off two H ions from every molecule, it would have in chemically equivalent quantities twice the number of H ions found in HCl." The author just referred to evidently had an erroneous view as to what chemical equivalent quantities meant, although he had previous to this published some papers (one of which has already been referred to) on a similar character of work. Hence it may be seen that care, both in preparing and in naming solutions, is very desirable.

The solutions used in the following experiments were selected because they represent the chief types,—acid, base, and toxic salt. The carbonate and the bicarbonate were used in order to see how physiological reactions might harmonize with the theory of electrolytic dissociation. Carbonic acid presented a peculiar aspect of the question, inasmuch as it is an acid which is said to dissociate, and yet it produces almost no toxic effect at the highest concentration obtainable.

The method of marking and of measuring the radicles, and the test applied to decide the question of death, were according to the method of Loew[6], namely, that of a growth in water after having been submitted to the solution test. If growth took place in the solution, and then in water, the radicle was considered living; but if no growth took place in water—after the twenty-four hours in the solution—the radicle was considered dead. For measuring the growth of the pea and the corn, a mark was made on the glass vial on one or both sides; then sighting through in line with the root tip, measurement could thus be made very accurately, and certainly very conveniently. In the case of the lupine, a mark was made with india ink at, or a little below, the junction between the root and stem; and this mark kept above the solution. Measurement was made from this mark to the end of the root tip and recorded.

An attempt was made to follow the method of marking adopted by Heald, and Kahlenberg and True, but it was found too clumsy for the purpose, mainly for the reason that the india ink would "run" so as to leave the mark upon the root broad and indefinite, and in some cases the mark was entirely lost when the portion of the radicle on which the mark was made was in the solution.

The seedlings used were *Zea mais* (common field corn, yellow dent variety), *Pisum sativum* (small field pea) and *Lupinus albus* (white lupine). These were selected chiefly because they were convenient for the purpose; and also because other inves-

* This Journal, vol. ix, March, 1900, p. 184.

tigators had worked with the same kind of seedlings, rendering comparison of results possible. Seedlings were prepared in the usual way, and were used when the radicle was of a suitable length. However, none was used whose radicle was less than 12^{mm} in length.

For the test in regard to physical affinity, a pure sand was obtained from ground quartz. This was thoroughly washed, first in strong HCl, then in water, and lastly in distilled water several times. Two grades were secured, *fine* and *coarse*. The particles of the fine sand were of such a size that the volume of one grain was $\cdot 0655^{cbmm}$, and a grain of the coarse sand $\cdot 22^{cbmm}$. The surface area of the fine sand is to the surface area of the coarse sand, therefore, as 3 : 2, in a given mass of sand. From this it is not to be inferred that all the grains were exactly of the same size. The measurements given are an approximation towards an average. A further test was made to see how great the volume of air space would be in the one as compared with that of the other. The following was the result of careful experiments: In a total volume of $15\cdot 6^{cc}$, there was, in the case of the fine sand, $5\cdot 6^{cc}$ of air and 10^{cc} of sand. Of the coarse sand, in a volume of $15\cdot 6^{cc}$, there were $6\cdot 0^{cc}$ of air. Both were tested as nearly as possible under the same conditions of packing. Several tests gave the same result. It thus appears that the coarse sand contained a little more air space than did the fine,—actually 38·4 as against 35·9 per cent, in proportion to total mass of sand and water.

The volume of sand used per seedling was 12^{cc}, and 8^{cc}, in the case of both kinds of sand. As no difference was observed in regard to growth whether the quantity was 12^{cc} or 8^{cc}, no mention is made in the records.

Some of the experiments seemed to show that the shape of the vessel in which liquid tests were made had a perceptible influence upon the power of the seedling to resist the toxic action of the solution, resulting possibly from inequality of diffusion. But in all tests recorded in this paper, the vessels were homeopathic vials of uniform proportions for all the sizes (from 25^{cc} to 1^{cc} capacity).

For corroborative tests, the seedlings were germinated in calcium chloride tubes, the "seed" remaining in the bulb and the radicle growing down through the small end. Manipulation was thus very convenient, and the minimum of damage done the seedling in the process of transfer and of marking. This test was made only with seedlings whose radicles had penetrated *beyond the end of the tube.*

The different tests used by the various investigators to decide death renders it extremely difficult to make comparisons. The

test here, as has already been stated, is the capability of making further growth. In nice distinctions the mere appearance is not a sufficient test; but strange as it may seem, this has been the most general criterion. However, in the most critical point this test fails. Jones (Theory of Elect. Chem., p. 269) states: "It was a simple matter to determine when the root was dead, since it lost its satiny lustre and acquired a dead white color." This is just what it is almost impossible to do. Cameron* gives it as a test of death that when the first 15^{mm} became flaccid, death resulted. From this it may be inferred that, if the radicle became flaccid the first 13^{mm}, or the first 10^{mm}, or even the first 5^{mm}, the seedling would be recorded as *living* in that solution. Where the radicles did not become flaccid at death he does not say how he decided the matter. He contents himself with saying that it required *much experience* and *nice judgment.*

Vagueness is occasional even in measuring. Kearney and Cameron (l. c.) state: "The radicle had somewhat elongated from the plumule to the apex." They may mean from the terminal bud to the apex of the root; or, possibly from one end of the radicle to the other, two very different things.

The tables contained in this paper (unless otherwise stated) are records of *average* experiments of each type. It would occupy far too much space to give all the records, because a large number of experiments were made in each class, often as many as twenty seedlings being submitted to the test. Experiments were frequently repeated, sometimes out of mere curiosity, but all the evidence obtainable was used to strengthen whatever results are here set forth. One or two seedlings, in a test of this nature, is not enough. Occasionally a seedling will die, even in water, and it is extremely difficult to tell why.

To show an example of the comparisons of growth made in regard to quantity of solution used, one experiment is here below recorded.

I.

PEA, HCl $n/2048$.

Quantity of solution.	Growth in 24 hours in solution.	In water, growth in 24 hours.
25^{cc}	0^{mm}	0^{mm}
20	0	0
12	0	0
8	0	0
5	3	0
2½	12	11
1	12	16

Such experiments as the one whose results are just given form the basis for the figures in Tables II–IX.

* Journal Phys. Chem. xiii, 3, 1904.

The columns in the following tables (I–IX), under concentration used, are divided into four parts, and these are subdivided,—A, B, C, D. In the column A is given the number of cubic centimeters in which the radicles plainly lived and grew. In B is given the number of cc. in which the radicles died. Column C contains the average number of mm. the radicles grew during twenty-four hours' immersion in the solution used. This number is not the maximum average, that is to say, it is not a measure of the growth which might be obtained in a quantity of solution much less than the one given in column A. In column D is recorded the average growth obtained in twenty-four hours when the radicle was in water, after having been taken from the solution. This also refers to the seedlings grown in a quantity as indicated in A.

II. H_2SO_4.

	n/1024				*n*/2048				*n*/4096				*n*/8192			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Pea					2½	5	5	5	5	8	7	4	12	25	3	0
Lupine					5	8	5	7	12	20	2	6	25		7	9
Corn	1	2½	5	14	12	20	5	10	20	25	5	2				

III. HCl.

	n/1024				*n*/2048				*n*/4096				*n*/8192			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Pea					2½	5	12	13	5	8	8	4	12	20	8	2
Lupine					2½	5	12	22	5	8	3	8	20	25	8	3
Corn	1	2½	8	10	2½	5	12	10	12	20	6	3	25		13	3

IV. H_2CO_3.*

	n/171				*n*/343				*n*/513			
	A	B	C	D	A	B	C	D	A	B	C	D
Pea					20	25	11	12	25		12	15
Lupine	25		7	3								
Corn	25		16	35								

V. $CuSO_4$.

	n/32768				*n*/65536				*n*/131072				*n*/262144			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Pea	2½	5	16	0	8	12	18	0	12	20	4	0	25		10	6
Lupine	5	12	4	6	25		7	30								
Corn									1	2½	3	13	20	25	7	8

* This is considered a divalent acid, though Cameron regards it as a monovalent acid (HCO_3).

VI. KOH.

	$n/64$				$n/128$				$n/256$				$n/512$			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Pea									4	8	11	4	25		15	12
Lupine					4	8	11	8	25		12	13				
Corn	1	2½	6	4	25		13	11								

VII. NaOH.

	$n/64$				$n/128$				$n/256$							
	A	B	C	D	A	B	C	D	A	B	C	D				
Pea					3	8	7	8	25		8	12				
Lupine	1	2½	3	10	25		9	6	25		12	10				
Corn	2½	5	12	15	25		19	16	25		16	12				

VIII. Na_2CO_3.

	$n/32$				$n/64$				$n/128$				$n/256$			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Pea													12	25	10	7
Lupine									8	20	10	5	25		8	9
Corn					12	20	10	5	20	25	8	3	25		6	4

IX. $NaHCO_3$.

	$n/8$				$n/16$				$n/32$				$n/64$			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Pea					3	8	3	2	8	12	7	11	12	20	3	6
Lupine					20	25	4	5	25		5	6	25		13	35
Corn	1	2½	3	8	25		7	6	25		9	20	25		12	42

During the course of many of the experiments made with radicles immersed in solution, certain phenomena seemed to indicate that the action which took place between the substance in solution and the radicle was chemical in its nature. Consequently, experiments were made to ascertain, if possible, how much reaction the radicle might produce if allowed to react upon the solution for a given time. Two of these experiments are here recorded, one of them employing $HCl, n/1024$ and the other $H_2SO_4, n/1024$. In both cases corn seedlings were used. In column 1 is given the volume of solution used in each case; in column 2 is given the growth in millimeters of the radicles during twenty-four hours; then these seedlings

were taken from the solution and fresh seedlings put in their places in the same solution. In column 3 is recorded the growth of seedlings during one day,—the second day the seedlings were used. These were, of course, the same solutions which had been used the previous day. This was continued for eight days. In column 6 is the recorded growth for two days. In all other cases the growth is for a period of twenty-four hours. The same solutions, therefore, were employed for eight days, and seven series of fresh seedlings were used in the test.

X. Corn, HCl, *n*/1024.

1. Quantity of solution.	Growth at the end of,—					
	2	3	4	5	6	7	8
	1 dy	2 dy	3 dy	4 dy	6 dy	7 dy	8 dy
25cc	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0
12	0	0	0	17	12	8	23
8	0	0	0	14	20	13	28
5	0	8	3	9	10	*	*
2½	0	8	20	22	18	*	*
1	8	10	2	24	*	*	*

XI. Corn, H_2SO_4, *n*/1024.

1. Quantity of solution.	Growth at the end of,—						
	2	3	4	5	6	7	8
	1 dy	2 dy	3 dy	4 dy	6 dy	7 dy	8 dy
25cc	0	0	0	0	0	0	0
20	0	0	0	0	8	5	10
12	0	0	0	6	6	8	25
8	0	0	10	24	16	7	24
5	0	14	15	22	8	*	*
2½	0	12	30	22	20	*	*
1	5	14	13	20	*	*	*

From these tables it seems reasonably clear that *quantity* of solution bears certain relations to toxic action. In Table I is shown a sort of limit in quantity, somewhere between 2½ and 5cc, the seedlings plainly living in quantities of 1 and of 2½cc; while they just as plainly died in quantities ranging from 5cc up through 25cc. The action is probably a chemical one, resulting from the substances supplied to the solution by the plant; or, it may possibly be a physical action produced upon the solution by merely extracting certain substances mechanically from the solution. It is by no means easy to decide which

* No tests were made, as growth was quite evident.

it may be. In each case the toxic action of the solution is reduced; in the former by neutralization and in the latter by extraction of the harmful element. This is plainly shown in Tables X and XI. Each seedling makes the solution less toxic, as is shown from the fact that on the first day the seedlings lived in a quantity of 1^{cc} in the case of both acids, while on the eighth day they lived in a quantity of 12^{cc}.

Larger quantities than 25^{cc} were used, but no difference was noticed. In fact, when two or three seedlings were placed in a beaker (100^{cc}) with radicles immersed, it usually happened that they stood the concentration better than when placed singly in vials containing only 25^{cc} of solution.

Small quantities, as a rule, gave the most clear-cut reactions, probably because of the fact that diffusion in solutions is so very slow, making it possible for a considerable quantity of the solute or of the ions to lie in a part of the solution too far from the radicle of the seedling, to affect it. But in the case of small quantities, diffusion will enter into the problem to no very great extent, rendering it possible to obtain results which are more nearly accurate from a chemical point of view.

The actual amount of toxic ions overcome in 24 hours by a seedling of corn with H_2SO_4 and HCl is 1^{cc} of $n/1024$, giving a result of $1/000 \times 1/1024 = 1/1024000$ grams of ionic hydrogen. This may be expressed in another way:—1,024,000 seedlings would resist the toxic action produced by one gram of ionic hydrogen. It may be proved absolutely, as indicated in Table II, column A, of a concentration of $n/1024$. For, if a gram-equivalent solution be diluted to $n/1024$ and divided up into quantities of 1^{cc}, and a seedling be placed in each, they would all grow; but if divided up into quantities of $2\frac{1}{2}^{cc}$, and a seedling placed in each, they would all die. For more dilute solutions, the seedling can live in the presence of a far greater amount of ionic hydrogen, showing that diffusion is remarkably slow and that the action of the mass of the water is considerable. The number of gram-ions in a solution $n/2048$ would be half as many per unit of volume; but the corn seedling lives when submitted to 12^{cc} of this solution. It ought, however, to withstand only 2^{cc}, if diffusion were perfect and mass action eliminated. Consequently, the injurious ions in 10^{cc} of the 12^{cc} used are prevented from acting upon the radicle from the fact that the mass of liquid is great enough to render $10/2 \times 1/102400$ grams of ionic hydrogen harmless, when in a quantity of 12^{cc}. This is the condition of affairs with corn for H_2SO_4. It is apparently different with HCl at the dilution mentioned but similar at the next lower dilution. Where the seedling is particularly sensitive to the solution, as with the pea, there is small difference in relatively great concentra-

tions, the difference being greater and greater as the amount of solution increases. So that beyond a certain limit of concentration, no matter how much ionic hydrogen be present, this hydrogen is prevented from acting on the radicle by the mere presence of the mass of water. This is probably because diffusion is so very slow. The corn seedling theoretically should resist 1, 2, 4, 8^{cc} of HCl in the 4 dilutions given in Table III, if diffusion were perfect. But it does actually resist 1, $2\frac{1}{2}$, 12, inf., Table III, so that the difference in quantity due to mass action is represented by the differences between the pairs of numbers in the series thus,—0, $\frac{1}{2}$, 8, inf. Now, in $n/8192$ the lupine or the corn will counteract the harmful ions as fast as they come in contact with the radicle, so that the dilution at which the seedling lived in 25^{cc} may be said to be the dilution where diffusion and vital activity are balanced. The limit of resistance, therefore, for corn is 1^{cc} of $n/1022$; and of 25^{cc} $n/8192$.

It has been pointed out (3, l. c. p. 90) that lateral roots which develop after a seedling is placed in a test solution may live and grow even though the radicle itself be killed. Kahlenberg and True suggest that this is due to a power of accommodation, but this is quite probably not so, because in a number of experiments with seedlings which had withstood one solution, an attempt was made to have them grow in a solution a grade stronger, or in the same solution in greater quantity, but without success. Seedlings showed no power of accommodation. It is more probably due to the fact that the radicle has already partly neutralized the solution, as appears in Tables X and XI.

The strongest solution of carbonic acid (H_2CO_3) which it was possible to obtain was $n/171$ by actual titration test. Seedlings of corn and lupine stood this concentration readily, but the pea did not. With the largest quantity of solution used (25^{cc}) the pea survived in $n/513$ but died in $n/342$.

H_2CO_3, according to the theory of dissociation, may dissociate into H ions and CO_3 ions, or possibly into H ions and HCO_3 ions, more probably the latter, reasoning from such data as we have concerning $NaHCO_3$. Neither case can be true, speaking in the language of the theory of electrolytic dissociation, because, if there were H ions present in such quantity as is indicated by a dissociation into H ions and CO_3 ions, then it would be as toxic as H_2SO_4, but, from those experiments, it can scarcely be one-fiftieth as toxic. The other alternative method of dissociation can not account for this either, for a similar reason. These results are in opposition to the theory of dissociation.

The experiments with sodic carbonate show that the corn seedling endures a solution of $n/128$ in 25^{cc}. From the side of the theory of dissociation this substance should permit

growth at about $n/16$, because sodic chloride, which is about 5/6 dissociated at this concentration, permits growth. The sodium, in the case of NaCl, appears to be but slightly toxic. Nor can the CO_3 ion be very toxic, from Table IV. Whence then this great toxic action of Na_2CO_3? Basing our views upon the theory of electrolytic dissociation, it ought to be about the same as NaCl or Na_2SO_4. But it is far more so. From this it would seem that the theory was insufficient, or possibly erroneous. The explanation, in the writer's opinion, is that the Na_2CO_3 breaks up, in aqueous solutions, into Na_2O and CO_2 and then reacts thus:—$Na_2CO_3+H_2O = 2NaOH+CO_2$. It would then be practically a solution of NaOH of a concentration identical with that of Na_2CO_3, which was chemically equivalent. This is quite probable from these experiments. If this explanation be correct, the theory of dissociation may give very misleading notions as to the actual condition of affairs.

The bicarbonate of soda affords another illustration. This may dissociate into Na and HCO_3, or into H and $NaCO_3$, or into Na,H, and CO_3. The experiments show that the pea will grow in 25^{cc} $n/128$ and in NaOH $n/256$. If the bicarbonate dissociate according to the first plan, the seedling ought to live in a solution about $n/8$; and if according to either of the latter, in a solution of about $n/2048$. It, however, does neither.

Pea seedlings will live in small quantities of the bicarbonate at a strength of $n/16$ and in similar quantities of NaOH at $n/128$, but in chemically equivalent quantities there is just half as much sodium in the bicarbonate as in the hydroxide. They would compare then at about 4:1 in toxicity, the hydroxide being the stronger. But since this substance may dissociate in three ways at least, we may have a dissociation as follows, with possibly an accompanying chemical action; $8NaHCO_3$ produces $Na_2O + 2CO_2 + H_2O$ and 6Na and $6HCO_3$. This might easily give a chemical reaction from Na_2O and H_2O of 2NaOH. Hence from 8 molecules we get 2 molecules of NaOH or 2 OH ions. The ions Na_3 and HCO_3 are probably harmless, judging from Table IV. This is in the language of the theory. These explanations throw some light upon the alkaline reaction on litmus, and other indicators, of the so-called acid salt $NaHCO_3$. Theoretically it ought to react acid, if anything, but practically it reacts rather strongly alkaline.

Similarly also with Na_2CO_3. Theoretically it ought to be neutral, but it actually reacts very strongly alkaline. The explanation, therefore, is, that in the process of dissolving in water, an actual chemical reaction takes place by some rearrangement of the molecules, or groups of molecules, in the solution. The ionization theory does not aid at all, rather the

reverse. Ionization *may* take place, but a further reaction must be assumed in order to account for the phenomena referred to, both chemical and physiological.

In order to test the effects of a foreign body upon the solute, pure clean sand (silica) was mixed with the solution, and the radicle immersed in the mixture. The vials were of similar proportions to those used in the liquid tests. The actual net volume of the sand employed was from 5 to 8^{cc}, and of liquid $3\frac{1}{2}^{cc}$ to 6^{cc}. Each seedling was exposed two days to the mixture, and afterwards tested for further growth in water. One reason for exposing two days instead of one—which was done with the liquid tests—was to make absolutely certain that whatever deductions in regard to power to resist the toxic reagent, should be on the safe side, because some seedlings can endure a solution for one day when they could not for two days.

In column A, under the given concentration, is placed the average number of mm. the radicle grew in length during forty-eight hours; and in column B the average number of mm. the same seedling grew when immersed in water after being removed from the mixture (solution with sand). In one respect, therefore, the test was a severer one than when the seedlings were immersed in the liquid, because they were exposed to the reagent twice as long.

II.a, H_2SO_4.

	$n/256$		$n/512$		$n/1024$	
	A	B	A	B	A	B
Pea	0	0	14	8	6	10
Lupine	0	0	13	10	13	3
Corn	3	0	22	29	25	15

III.a, HCl.

	$n/512$		$n/1024$	
	A	B	A	B
Pea	6	2	27	10
Lupine	4	5	24	6
Corn	29	17	35	15

IV.a, H_2CO_3.

	$n/171$	
	A	B
Pea	8	9

V.a, $CuSO_4$.

	$n/2048$		$n/4096$		$n/8192$		$n/16484$	
	A	B	A	B	A	B	A	B
Pea	2	0	4	3	4	7	28	17
Lupine	7	0	5	6	10	3	13	14
Corn	2	0	16	5	23	10	3	4

VI.a, KOH.

	n/32 A	n/32 B	n/64 A	n/64 B	n/128 A	n/128 B
Pea	0	0	3	0	10	12
Lupine	0	0	4	0	11	5
Corn	0	0	12	10		

VII.a, NaOH.

	n/32 A	n/32 B	n/64 A	n/64 B	n/128 A	n/128 B
Pea	0	0	1	0	18	16
Lupine	0	0	0	0	6	4
Corn	0	0	11	10	17	11

VIII.a, Na_2CO_3.

	n/8 A	n/8 B	n/16 A	n/16 B	n/32 A	n/32 B
Pea	0	0	0	0	8	5
Lupine	0	0	2	0	9	7
Corn	0	0	5	0	28	11

IX.a, $NaHCO_3$.

	n/4 A	n/4 B	n/8 A	n/8 B	n/16 A	n/16 B
Pea	0	0	0	0	8	9
Lupine	0	0	3	0	6	7
Corn	0	0	15	11	2	2

A comparison of data taken from Tables II–IX (those in which radicles were immersed in liquid) with those taken from Tables IIa–IXa (those where radicles were immersed in sand and liquid) may help towards a clearer notion of the action produced by a non-chemical body. In making comparisons, the actual mass of solution used was arranged so as to have, as nearly as possible, the same in each case, with a view towards eliminating every element of inequality excepting the one under consideration. It proved, however, that a difference in quantity, ranging from $3\frac{1}{2}^{cc}$ to 6^{cc}, of actual liquid used, when mixed with sand, produced no noticeable difference in action upon the radicles.

In solutions of HCl and H_2SO_4, $n/512$, all seedlings mentioned, live with at least 3^{cc} of liquid, when sand is present; but in liquid alone, similar seedlings, under similar circumstances, can scarcely endure a concentration of $n/2048$, or in a ratio of 4 : 1. This shows that the actual physical effect of the sand was equivalent to a neutralizing reaction of $9/2048^{cc}$ normal acid in 1^{cc} of solution, because the seedling lived in a solution $3/512^{cc}$, or 12/2048 of normal acid to 1^{cc} of solu-

tion. When in liquid alone, radicles withstand barely 3^{cc} of $n/2048$* solution, or $3/2048^{cc}$ per 1^{cc} of normal acid; therefore 9/2048 represents the physical effect of the sand with the two substances used. This is about 4:1, at or near the limit where root tips just resist the acid and live.

Similarly for KOH and NaOH, with the pea and the lupine, the sand retards the action of 3/256 of 1^{cc} of normal KOH near the resisting limit. For KOH and corn it is 3/128 of 1^{cc} normal.

The seedlings withstood relatively a very great concentration of $CuSO_4$ when sand was present; actually $n/4096$ (Table Va) as against not less than $n/32768$ without sand. This seems to be due again to the presence of the non-chemical body. The reason why the toxic action is so much reduced with this substance is probably because, as has already been mentioned, the attractive force of the sand is constant, and requires satisfaction; therefore, in dilute solutions, where there is so much less of the solute per unit of volume, the seedling would be relieved of a large proportion of the harmful element. The actual amount for this solute would be $3/4096 - 3/32768 = 21/32768$ gram-ions of copper. This hindrance to toxic effect of the solute is probably also due in some measure to the retarding effect upon diffusion caused by the presence of the foreign body.

The suggestion which arises from this non-chemical action of sand is that soils may hold mechanically a portion of a solute, and may never give it up. It may be forced to liberate a part of it by the application of another solute which might, in part, satisfy the attractive force exerted by the particles of soil. This may also account for the fact that a chemical analysis is not always a final argument as to the fertility of soil. For instance, suppose KNO_3 were applied in a certain quantity to a pure sand, and plants be allowed to grow for a time in this, it would be found that the plants had been unable to extract all the KNO_3; but if another substance, say $Ca(NO_3)_2$, be then applied, the amount of KNO_3 available might be increased, though no chemical action take place. It is probably thus with the whole subject of fertilizers. A substance may often liberate an important element by taking its place mechanically in the soil, though the substance which had been applied have itself no fertilizing value. The writer is aware that many consider a chemical analysis of soil a definite basis for a liquid nutrient solution, and *vice versa*. Cameron. (Bul. 22, U. S. Dep. Ag., p. 15), quoting Johnson, states: "The analysis of the well water shows that a nutritive solution need not contain

* **Slight exceptions to this may be noticed as shown in Table II, but calculations are made only from the most certain limits.**

the food of plants in greater proportion than occurs in the aqueous extract of ordinary soil." This is probably the reverse of the actual condition, because, as has already been pointed out, the soil particles have a physical attraction to be satisfied.

The question of selective power of plants is a vague one. It is probably more a name than a fact. The soil selects as well as the plant.

So far as this physiological problem is concerned, it seems that the theory of electrolytic dissociation is insufficient. Certainly no support to the theory comes from the physiological side. Acetic acid, sodic carbonate, sodic bicarbonate and carbonic acid exhibit phenomena quite in opposition to it. Conclusions have been published which, from the data, seem to be entirely unwarranted. Cameron virtually points this out, saying: "The necessity of such assumption would seem to absolutely invalidate the use of such organisms and criteria for the testing of the dissociation hypothesis in any quantitative way." On the other hand, in Jones' 'Theory of Electrical Dissociation,' p. 272, is stated: "The theory of electrolytic dissociation has thus thrown light upon the physiological action of different substances, and the theory has itself been strengthened by these experiments upon living things." Now the experiments recorded in this paper show that the theory throws no light upon such physiological problems, rather the reverse, if anything. A further quotation will show that Jones did not examine the matter as carefully as might be expected, in consideration of the fact that he was compiling a text-book. He states, p. 271, referring to the work done by Heald: The Cu ion is about as toxic as the hydrogen ion," and on page 270: "In the case of strong acids the root would just live in a solution which contained a gram molecular weight of the acid in 6400 liters," and further on: "The roots would just survive in a solution which contained a gram molecular weight of copper ions in 51200 liters." It should be remembered that these quotations from Jones are taken from a recent text-book. A glance at them will convince one that little, if any, care has been taken to present the matter accurately. This is a misinterpretation of Heald for which Heald is in no way responsible.

In the first place, there is no evidence from the physiological side for the theory of electrolytic dissociation, and in the second place, references have been made over and over again to the earlier investigations, with no sure foundation. When these creep into text-books, it is supposed they are considered to be established facts, and, therefore, all the more need to call attention to them.

An illustration may show the mistaken notion following the application of the theory of dissociation to explain certain

physiological phenomena. Heald (l. c., p. 136) states: "Now the carbonic acid in aqueous solutions will dissociate to form H ions and CO_3 ions." This is of course quite probably not correct. He states further, p. 137: "More experiments are necessary to prove conclusively the fact that CO_2 poisoning is due to the effect of the ionic H, and as soon as possible experiments with that view will be carried out." From this latter quotation it is quite clear the author had no experimental evidence in regard to H_2CO_3, yet in the same connection he asserts it as a fact that it dissociates into H ions and CO_3 ions. If the toxic action be due to the H ions,—assuming his prediction of the substance to be warranted—it should be as toxic as H_2SO_4. But it is only about one-fiftieth as toxic as H_2SO_4. This is an illustration of prediction based on the theory of dissociation without basis in fact. The author just referred to is not alone in this respect; and the whole tendency, the whole spirit of the paper, as well as those of some others, seems to *assume the theory of electrolytic dissociation is true, and see if physiological action fits in;* and where it does not, as in acetic acid, *make it fit by assigning function to the whole molecule.*

A cursory glance at the situation might lead one to suppose that the apparent uniformity of toxic action of certain substances, e. g., HCl and H_2SO_4, did show a sort of harmony with dissociation. However, a careful examination of this reveals the fact that it is quite to be expected that these substances would act thus, for the simple reason that they are *chemically equivalent* as a basis of operation. It is not to be wondered at, therefore, that there is such harmony. It could scarcely be otherwise: and so on along the whole line, whether dissociation occurs or not. The only fair conclusion seems to be that the toxic action is a chemical action, because all concentrations made use of are *chemical equivalents.* Jones, p. 268, states: "It had been thought that the physiological action of any substance was due to its chemical nature." Kahlenberg and True, p. 85, state: "It has always been taken as axiomatic that the physiological action of any substance is due to its chemical character." Notwithstanding these statements, from the experiments recorded in this paper, *it should be still so considered.* There seems no doubt whatever that the physiological action is due to the chemical properties of the solute. Though the writers just mentioned do not attempt to explain what the nature of the action may be, they lead one to infer that it is due to some subtle action of a physical nature, involving, it may be, a charge of electricity with which the ion is thought to be loaded.

Dissociation under ordinary circumstances may not take

place at all. The only reliable test to the matter is the conduction of electricity. But this very test may actually *bring about* dissociation, instead of merely showing that it already exists in the solution. Moreover, the theory of the cause of osmotic action does not throw light upon the matter, as notice the results of Morse and Frazer* on sugar solution—a non-electrolyte. They obtain a pressure of about 32 atmospheres, where, according to the theory of dissociation, it ought to be but 22·6. The high vapor densities of certain substances and the lowering of the freezing point of solutions may be explained on other grounds upon which it is not necessary to enter here.

The toxicity of compound ions,—those which are composed of more than one element,—has been discussed by Clark and by Kahlenberg and True, but with diverse results. Clark concluded somewhat generally that a compound ion was *more* toxic than a simple ion. The experiments of Kahlenberg and True lead one to the conclusion that the compound ion is much *less* toxic. They state, referring to such compounds as H_3PO_4, that the acid dissociates into H and H_2PO_4, and the acid H_3PO_4 is equally toxic with HCl. This shows that they consider the H_2PO_4 ion as practically non-toxic, or slightly so. They state further, referring to potassium silver cyanide, that the complex ion Ag $(CN)_2$ is far less poisonous than the Ag ion alone. They say also that ferric ions are much more poisonous than are the complex ions containing ferric iron. Clark, on the other hand, reasoning also apparently from the theory of dissociation, referring to H_2SO_4 states that the ion HSO_4 is 1·3 times as toxic as H, and that the whole molecule (HNO_3) is 7 or 8 times as toxic as the simple ion H.

No attempt is here made to reconcile these statements, for it is impossible to do so. But it shows quite clearly that it is also impossible to reconcile the theory of dissociation with experimental evidence. It shows further, that one can not predict just what will be the physiological result if the basis for prediction be laid upon the theory of dissociation.

Another illustration of the danger in attempting to harmonize the theory of dissociation with physiological phenomena, is furnished by a comparison of toxic action between Na_2SO_4 and NaCl. Cameron places the toxic limit of the former at $3n/400$, and True places that of NaCl at $n/16$.† Now, according to the theory of dissociation (as discussed by Kahlenberg and True), there appears a contradiction; for, since the anion is a negligible quantity in each case, the kation must account for the difference, but the kations are identical. The difference above noted is also too large to be a mere personal difference. Assum-

* Science, ii, 16, 883.

† Cameron gives the limit for NaCl at $n/50$, which is probably correct.

ing Cameron's figures, there is still a wide difference between these two salts with a common kation. But it might be argued that the anion may cause the difference. Let us assume it does. Then, in the case of H_2SO_4 and HCl we have a common kation again, with each of the two anions before mentioned. A comparison of these ought to show H_2SO_4 more toxic than HCl. But all experiments prove rather the reverse. HCl is slightly more toxic (see Tables X, XI, I, II.) Even assuming Kahlenberg and True's own figures for these substances, we find no greater toxic action for H_2SO_4. Considering the comparison between NaCl and Na_2SO_4 we should expect to find it decidedly more toxic.

XX.

		Liquid test.			Liquid and Sand test.
1	2	3	4	5	6
H_2SO_4	pea	2048	2½	16382	512
"	lupine	2048	5	8192	512
"	corn	1024	1	8192	512
HCl	pea	2048	2½	16384	512
"	lupine	2048	2½	16384	512
"	corn	1024	1	8192	512
H_2CO_3	pea	343	20	513	171*
$CuSO_4$	pea	32768	2½	262144	4096
"	lupine	32768	5	65536	4096
"	corn	131072	1	524288	4096
KOH	pea	256	4	512	128
"	lupine	128	4	256	128
"	corn	64	1	128	64
NaOH	pea	128	3	256	128
"	lupine	64	1	128	128
"	corn	64	2½	128	64
Na_2CO_3	pea	256	12	512	32
"	lupine	128	8	256	32
"	corn	64	12	256	32
$NaHCO_3$	pea	16	3	128	16
"	lupine	16	20	32	16
"	corn	8	1	16	8

* $n/171$ was the highest concentration we were able to obtain, and both the lupine and the corn withstood this readily in a quantity of 25^{cc} and upwards.

In Table XX is a recapitulation showing the quantities of solution and the concentration which the seedlings just endured. A comparison is also made between the liquid test and the sand test. In columns 3, 5 and 6 is given only the denominator of the fraction whose numerator is n. In column 4 is recorded the number of cubic centimeters in which the radicles just lived, and in column 5 is given the highest concentration the seedlings could withstand in a quantity of 25^{cc} or upwards.

It should be remembered always that the test applied to decide life was *further growth* in water after the seedling was taken from the test solution. Column 4 gives the number of cc. in which the radicle just lived at the concentration opposite in column 3. In column 6 is given the concentration the seedlings would endure when sand was present; the amount of solution to each radicle was 3½ to 6^{cc}, and the amount of sand about 5 to 8^{cc}.

A comparison between columns 3 and 5 in Table XX shows the variation due to *quantity* of solution. (It ought to be mentioned that when the experiments were arranged, the liquid used in all the vials of different size was taken from the same preparation, so that practically every element which might affect results was eliminated.) It may be seen further that a comparison of these results with those of Heald shows some difference of figures. No attempt is here made to reconcile these differences because a general *actual* toxic limit is not possible to obtain.

Column 6 shows clearly that the presence of sand affects the characters of the solution in regard to toxicity. In dilute solutions it reduces it enormously; in strong solutions not nearly so much. Though the figures opposite $NaHCO_3$ are close, yet if working with more closely graded quantities and concentrations slightly different results from those given might be expected.

The problem of soils, examined from this point of view, presents a very complicated question, from the fact that several substances enter into the composition of soil water. It is then a problem of permutations and combinations of $(n+1)$ substances, making factorial n cases for each combination. And, since the amount of each may vary from an insignificantly small to a predominating quantity, the number of problems from this side is at once enormous; and if the theory of dissociation be admitted into the proposition, the problem is still more complicated. There is then the possibility of ion effect, coupled with electrical forces, augmented or neutralized by the presence of a number of different ions.

In order to learn something of the differences in effect between fine and coarse sand, solutions of $CuSO_4$, $n/8192$, HCl, $n/512$, H_2SO_4, $n/512$ were compared with the following results: more growth was permitted in fine sand with $CuSO_4$ but, on the other hand, considerably more growth was permitted with coarse sand when HCl and H_2SO_4 were used. In all the experiments these were the general results, H_2SO_4 presenting the most marked character. One explanation of this may be that because of the greater surface, the fine sand would hold mechanically more of the solute when in very dilute solution

with heavy kations; whereas with stronger solutions and lighter kations, the centers of mass attraction being fewer, and the force consequently greater, the result might be that more light kations would be held by a mere force of attraction.

Two forces seem to be exerted, one by virtue of the surface exposed (surface tension so-called), and the other by virtue of the mass (gravitation). When the former encounters a substance which is attracted more by surface tension than it is by the mass, then the fine grains will exert a predominating influence upon the solute. When the latter encounters a substance which is more affected by mass than by surface tension, then the coarse grains will exert a predominating influence. At all events, we have the facts derived from the experiments, and it seems but fair to borrow explanations from the physics side of the question.

In the case of corn seedlings, an aquatic fungus frequently developed if the plants remained in the liquid for a few days. The tendency to curl has also been pointed out.

An investigation into the cause of the fungus growth showed that, near the root tip, some organic substance exuded from the plant. This substance contained some organic matter which acted, on heating, like sugar. When evaporated on a clean cover-glass, a syrup-like substance remained. For a further test, seedlings were allowed to send out aerial roots in a moist chamber under a bell-jar, and the root tips were then cut away at a point about 2^{mm} from the apex. In three hours a drop of clear liquid, about 2^{mm} in diameter, appeared at the cut end of the root. This drop, upon examination, proved to contain a large proportion of organic matter of a sugary nature, and a small quantity of ash of an alkaline reaction.

There is no doubt that this substance forms a nutritive material for fungi. Nor is it confined to the root tip, but may be found 20^{mm} or more from the tip. This was quite apparent in the sand cultures. Upon taking the corn seedlings from the culture media, whether sand or liquid, if the plant had not been killed, the liquid adhering to the tips and elsewhere was of a "glairy" consistency, slightly like white of egg, or like syrup.

The suggestion is here offered that the reason corn is enabled to withstand stronger solutions of acids and bases than some other seedlings, is in consequence of this secretion. Just what function this might serve is not known. At all events, a great loss to the plant, of organic food, may be suffered, if in cultivation the root-ends be bruised or broken.

In regard to the curling of the roots, it may be said that chemotropism has something to do with it, but just why it turns this way or that, in a solution where the forces are equally

distributed on all sides, is not easy to say. Such a curling is often seen in the radicles of corn seedlings grown in water or in the ordinary water-culture media. Cameron (l. c.) gets over the difficulty by saying: "They tended to curl up in an apparent effort to leave the solution, seeking a more congenial environment." This is assigning to plants a will-power we were not aware they possessed.

Summary.

Quantity of solution has an important bearing upon its power to affect the radicle; and rate of diffusion proves also to be of some significance.

Non-chemical* bodies retard very materially the activity of the solute in bringing about death to the radicle. In some instances the toxic effect was reduced 32 times by the mere presence of pure sand. The mere presence of the walls of the glass vessel has a perceptible effect in holding a substance mechanically; and the shape of the vessel is also not without some effect.

The action of the solute upon the radicle is very probably a chemical one.

There is no support to the theory of electrolytic dissociation from the physiological side. In fact, certain substances present phenomena which indicate opposition to it.

Both the carbonate and the bicarbonate, if they dissociate at all, do so in such a manner as to result in a chemical action upon the water, forming a hydroxide as one of the products.

Carbonic acid is of extremely low toxic power, killing the radicle of the pea at $n/342$, but not the corn nor the lupine at any concentration which it was possible to obtain ($n/171$).

Agricultural College, Michigan.

* After this paper was written, an abstract of a paper by True and Oglevee bearing, in part, on a similar line of investigation, appeared in Science Mar. 11, 1904, p. 421.

ART. XLIII.—*Tourmaline from San Diego County, California;* by DOUGLAS B. STERRETT. (With Plate XXIV.)

THE tourmaline crystals to be described in this article are from Damaron's Ranch, four miles northwest of Mesa Grande, San Diego County, California. A representative collection of over one hundred and sixty specimens given to Prof. Penfield by Mr. Ernest Schernikow of New York, and deposited in the Brush collection of the Sheffield Scientific School, was used for most of the investigation; which is here directed chiefly toward the study of crystal form. Additional notes were obtained from a brief examination of the collection on exhibition

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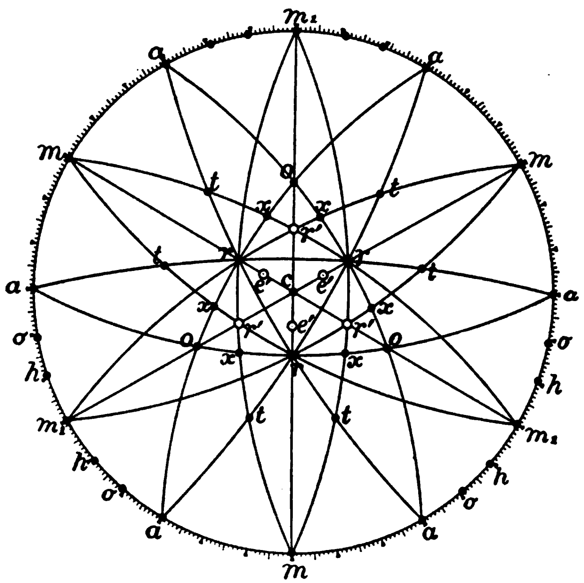


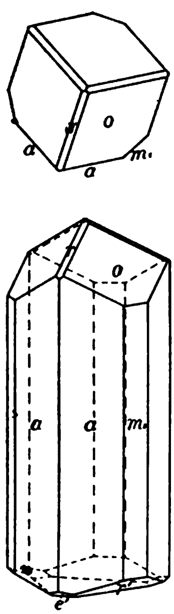
at the Natural History Museum, New York, loaned by Mr. Schernikow, and from the choicest crystals in Mr. Schernikow's possession. The crystals have evidently come from a pegmatite vein, as they are often associated with large quartz and feldspar crystals and bunches of lepidolite mica. They far surpass the crystals of Paris and adjoining localities in Maine in perfection of crystallization, and those of Haddam Neck, both in size and crystallization. It is also probable that no other locality produces stones with more varied and beautiful colors.

Many crystals are of gem quality, and according to "The Mineral Industry,"* $15,000 worth of gems were produced from this locality during the year 1901, and Mr. Schernikow places the value for 1903 between $40,000 and $50,000.

The number of forms found on the crystals is not great and only those common to tourmaline have been observed, a list of which is given in the accompanying table and shown in stereographic projection in fig. 1.

Prisms.	Upper end.	Lower end.
a $(11\bar{2}0)$	c (0001)	c' $(000\bar{1})$
m $(10\bar{1}0)$	r $(10\bar{1}1)$	r' $(01\bar{1}\bar{1})$
m_1 $(01\bar{1}0)$	o $(02\bar{2}1)$	e' $(10\bar{1}\bar{2})$
σ $(12\bar{3}0)$	t $(21\bar{3}1)$	
h $(14\bar{5}0)$	x $(12\bar{3}2)$	

2



The forms σ and h could not be accurately determined, for the prism faces of the crystal on which they were measured were badly striated. Reflections were obtained from thin glass strips glued on these faces, and gave results approximating to the above symbols. The character of the other crystals measured was such as to permit very satisfactory determinations of the forms enumerated, but it has not seemed necessary to publish a list of the angles measured.

Although owing to the hemimorphic character of tourmaline, the three r faces above form a triangular pyramid and not, strictly speaking, a rhombohedron, it will be convenient to refer to this and similar forms as rhombohedrons, and for like reason to call the t and x faces scalenohedrons.

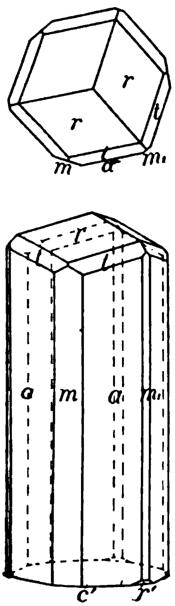
All of the figures drawn in clinographic projection have the antilogous end up, i. e., that pole which on cooling is positively electrified, and when tested by the Kundt method attracts sulphur. The crystals all follow the general rule, that the end with the steeper forms is the antilogous pole.

For a single locality the crystals show an unusual diversity of habit and color, and in describing them it will be convenient to divide them into types. In the first type the rhombohedron o forms the principal termination above, sometimes with a replacement of its edges by r, as shown in fig. 2. The lower

* Published by the Engineering and Mining Journal of New York.

termination when present is made up of c', r' and e' variously developed. The crystals show considerable variation in length; as a rule they are slender and the prisms are generally striated. No. 2 of the plate has been broken at the lower end and does not show its full length; while No. 3 and fig. 2 represent doubly terminated crystals. The colors are transparent pink or green throughout, or combinations of pink above and green below.

3



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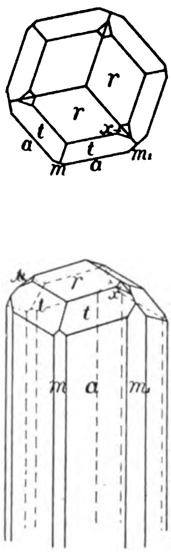

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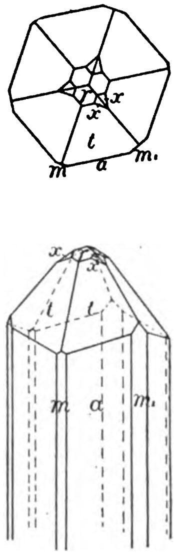


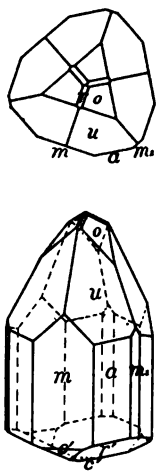
A second type is represented by figs. 3, 4 and 5, which are especially interesting because of the development of the scalenohedron *t*, and on some crystals a second scalenohedron *x* shows slight development. The lower termination when present generally consists of the basal plane and subordinate r', as shown in fig. 3. Most of the crystals are pink or rose color throughout; some are dark enough to be classed as rubellite; occasionally they are light green at the lower end. Some of the finest pink gems are cut from crystals of this type.

It is very unusual to have tourmaline crystals terminated as in fig. 5 by a large development of a scalenohedron. The brown tourmaline from Gouverneur, N. Y., shows a similar develop-

ment, but the scalenohedron is a steeper one, *u* ($32\bar{5}1$), and fig. 6 is here introduced for comparison.

The features of a third type are the number of prism forms and two bases, generally well developed, with subordinate rhombohedrons *o*, *r′* and *e′*, as shown in fig. 7. The crystals are, as a rule large; 7^{cm} high and 3^{cm} thick not being uncommon. The development of the rhombohedrons *o* and *r′* sometimes varies, with a consequent variation of the base; this forms a connecting link with the first type; for some crystals have only a small base with large *o* faces; if *c* were to fail entirely, the crystal might be considered of the first type.

6



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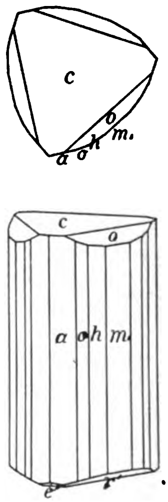
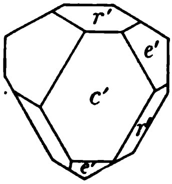


Fig. 6. Brown tourmaline from Gouverneur, N. Y., with scalenohedral development for comparison with fig. 5.

These crystals display a most remarkable variation of color, often of a quality unsurpassed by tourmaline from other localities. As an example, a description of one of the numerous crystals in Mr. Schernikow's collection will answer. Beginning with the lower end there is a layer of fine green; above this, bluish green fading into light rose color; then sea-green passing into smoky brown or brownish green; on this comes a cap of dark pink, appearing scarlet by reflected light. All of these colors, with the exception of the smoky brown, are trans-

parent and clear. One crystal has a lilac-colored band, formed by the blending of pale blue and pink layers.

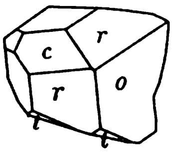
8



Crystals of a fourth type are often short and stout, terminated by basal planes and rhombohedrons. The prism zone is made up of deeply striated faces; or more properly speaking, layers of small crystals. The terminations consist of the bases and rhombohedrons, *o*, *r*, *r'*, and *e'*. The termination at the antilogous pole more often fails, and is generally rough and much corroded. Fig. 8 is a basal projection of the analogous pole of a distorted crystal of this type. These crystals commonly have a pink or white middle and green layers or cap at the ends. The corroded end is a dark semi-transparent green; while the other is transparent grass- or pale apple-green. One crystal has a cap of pale sulphur-yellow color. Other exceptions are white crystals, faintly tinted with pink and containing perfectly colorless portions.

Crystals of a fifth type have a black exterior or shell; generally less than a millimeter thick. Within there is a core of light colored material, green, pink or whitish. When the terminations are present, they are found to be *c*, *o* and *r* above with *c'* and *r'* below.

9



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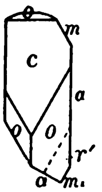

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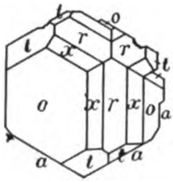
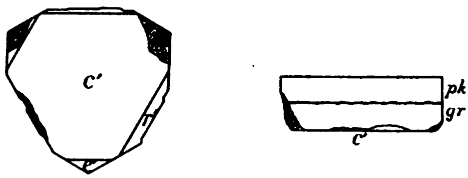


All of the crystals with an olive- or pistache-green color are included in a sixth type. Some are slender, as No. 1 of the plate; these are olive-green passing into brownish green at the upper end. Others vary up to 5^{cm} in thickness and often have a silky luster with pistache-green color. The upper termination of *o* and *r* sometimes appears, though the ends are generally etched and corroded. Crystals of all sizes, from that of a needle up, are found penetrating large crystals of quartz and feldspar.

Figures 9, 10 and 11 are end views of crystals so distorted as to be difficult to put under any special types. In fig. 9 the directions of the prism faces are not preserved on the crystal, so the outline was drawn as nearly as possible like the original.

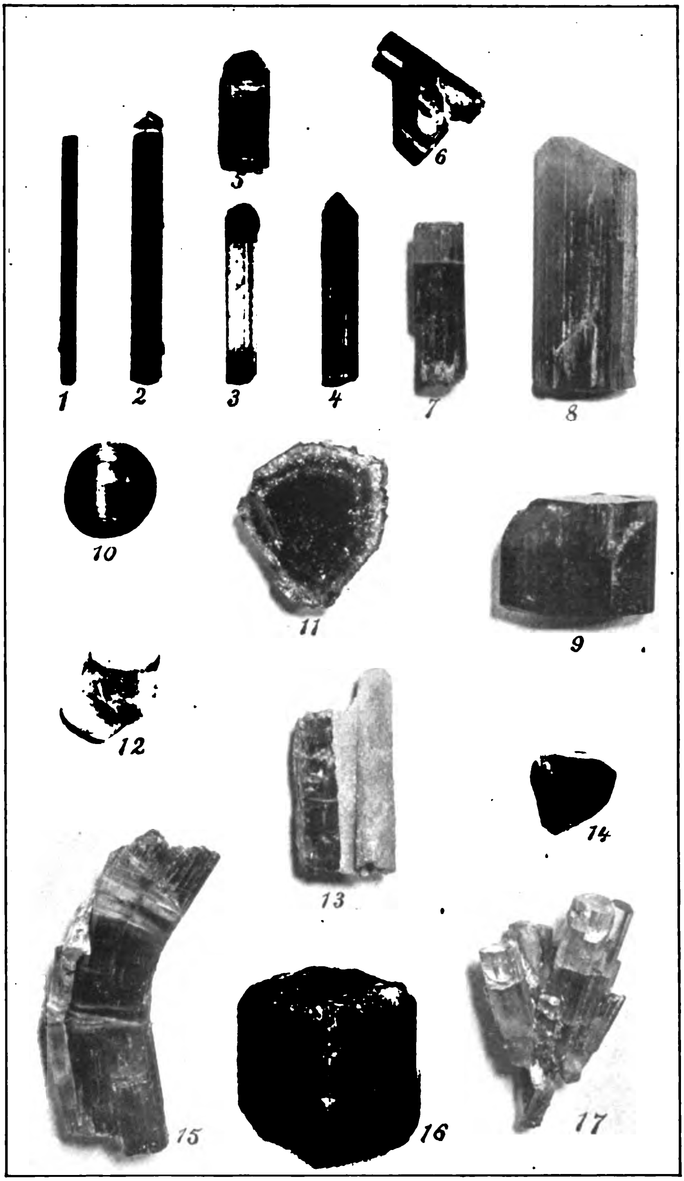
Fig. 10 is the same as No. 9 of the plate and is a doubly terminated crystal, the dotted line representing the development of one of the lower rhombohedral faces. The crystal shown in fig. 11 was loaned by Mr. Schernikow for examination and is unusual owing to the development of *x* and *t* modified by the presence of an *o* face. One *t* face (on the upper right hand side) is divided into two parts by a deep striation. Fig. 12 is an end and side view of a section cut from the lower end of a pale pink crystal with green cap. A natural basal plane *c'* forms one surface of the section, and is modified by small *r'* and *e'* faces. The intensity and thickness of the two colors are nearly equal and an interesting feature is that on looking through the section in the direction of the vertical axis, the two colors complement one another and a nearly white light is transmitted. Another transverse section with an oil-brown core and rose-colored exterior, each of the finest quality, gives a good illustration of the internal strain crystals may be subjected to, owing undoubtedly to variations in chemical composition; for in most positions under the polariscope, it gives a biaxial interference figure. Some crystals have internal striations parallel to the vertical axis, ending in little pits or etchings on the terminal faces, and when coarse, often partly filled

12



with clay. When these striations are fine and numerous, the crystals may be cut "en cabachon," and give most excellent cat's-eye effects.

In conclusion the writer wishes to express his sincere appreciation of the constant assistance and advice of Prof. S. L. Penfield in the preparation of this article; and also to acknowledge the courtesy extended to him by Mr. Schernikow.



TOURMALINE FROM SAN DIEGO CO., CALIFORNIA.

DESCRIPTION OF PLATE XXIV.*

1. Olive-green crystal of the sixth type.
2. Transparent, sea-green, with clear pink cap ; first type.
3. Crystal with colorless middle part and pale pink ends ; first type.
4. Transparent throughout; lower half pale green, upper half pink ; second type.
5. Pink with cap of exquisite rose color ; second type, same as figure 4.
6. Small pink prism penetrating the end of a quartz crystal.
7. Rough sea-green crystal passing abruptly into a pink cap at the upper end.
8. Distorted and flattened crystal of green color fading into pale pink at the upper end.
9. Distorted crystal shown in basal projection in figure 10 ; sea-green color with an almost colorless cap slightly tinted with pink.
10. Cat's-eye cut from a crystal with internal striations, which can be seen running horizontally through the stone.
11. Section cut from a crystal with a smoky brown core surrounded by a light greenish brown layer and pink shell.
12. Rounded bunch of lepidolite mica with albite adhering to the lower part.
13. Pink crystals coated with a crystalline incrustation of cookeite enclosing quartz and lepidolite.
14. Section broken across a crystal with a dark brown core and lighter colored shell.
15. Bent crystal ; the lower half is light pink passing into a pale green middle and back to pink at the upper end. Where the crystal had evidently been fractured by the bending, it has been healed by bands of fibrous tourmaline with silky luster.
16. A crystal of the fourth type. Grass-green cap at the upper end (analogous pole in this case), with white middle and corroded dirty green cap at the lower end.
17. Group of transparent pale pink crystals ; analogous ends free and terminated by c' and subordinate r'.

* Nine-tenths natural size.

ART. XLIV.—*The Limit of Error in the Volumetric Determination of Small Amounts of Gold;* by RALPH N. MAXSON.

[Contributions from the Kent Chemical Laboratory of Yale University—CXXVII.]

IN a former paper from this laboratory, Gooch and Morley* established the accuracy of a method for the determination of small amounts of gold, based upon the reaction

$$AuCl_3 + 3KI = 3KCl + AuI + I_2.$$

Recently the attempt has been made by Rupp† to show that this method is inaccurate, and to bring forward a process based upon the reduction of gold by standard arsenious acid, and titration of the residual arsenious acid by standard iodine. In a study of these two methods,‡ I have verified the results obtained by Gooch and Morley, but have been unable to determine similar amounts of gold with even approximate exactness by the method of Rupp.

More recently,§ Rupp has disclaimed accuracy for his method when applied to amounts less than a few milligrams, and proceeds to discuss the absurdity of attempting to determine volumetrically tenths and hundredths of a milligram of material, however accurate the method may be—and this in the face of his statement, in his own previous paper, of volumetric results carried to thousandths of a milligram.

While quite in agreement with Rupp so far as to admit the absurdity of attempting to determine amounts of material measured in tenths and hundredths of a milligram by means of N/2 arsenious acid, as did Rupp in three out of the six determinations upon which he rested his process, I take the view, that with properly made standard solutions of suitable dilution, it is quite possible for a skillful analyst to determine tenths and hundredths of a milligram of material.

By the use of approximately N/100 iodine and thiosulphate, Gooch and Morley got results with a mean error of 5/100 milligram between extremes of +3/100 mg. and −10/100 mg. in twelve determinations, a single small divided drop of the iodine solution and of the thiosulphate solution being sufficient to produce an immediate reaction with starch, and a bleaching of the starch color, respectively.

When using N/1000 solutions of iodine it was necessary to add to the volume used $0{\cdot}1^{cm^3}$ of iodine, in order that the first small drop of gold should bring out the starch reaction. This was a perfectly definite correction and was equivalent to 1/100 mg. of gold.

* This Journal (4), viii, 261, 1899.
† Ber. Dtsch. Chem. Ges., xxxv, 2011.
‡ This Journal (4), xvi, 155, 1903.
§ Ber. Dtsch. Chem. Ges., xxxvi, 3961.

With N/1000 solutions and with the application of this correction, ten experiments gave a mean error of less than 4/1000 mg. between extremes of +2/100 mg. and −29/1000 mg.; while in another series of experiments in which the start was made with pure gold foil, dissolved in chlorine water and treated by a process carefully described, the average error of fourteen determinations was +2/1000 mg. between extremes of +1/100 mg. and −8/1000 mg. This is not theory: it is experiment. Here are volumetric solutions capable of showing 1/100 mg., or less, of gold. Is it any more absurd to determine gold in this manner than to weigh that element upon an assay balance sensitive to 1/100 of a milligram? To be consistent, Rupp should include all processes, gravimetric as well as volumetric, in his sweeping declaration.

The fact that large percentage errors occur in certain determinations made by Gooch and Morley, upon small amounts of gold, is again made the subject of criticism by Rupp.

As I have previously stated, every analytical process has a certain inevitable error, and because of this fact as we approach the limit of accuracy of the process the percentage error will increase rapidly. This increase can, however, under no circumstances be considered a reason why small quantities of substances should be disregarded in analysis, either volumetric or gravimetric. Because the ordinary analytical balance is sensitive only to 1/10 or 1/20 mg. is no reason for declining to weigh tenths or twentieths of a milligram, although the percentage error in weighing such amounts may be very large.

Besides these wholly unreasonable criticisms, reference is made by Rupp to some matters of scientific fact, and to these I next propose to give attention.

To Rupp's statement that with dilute solutions the starch indicator is no longer reliable, it is sufficient to reply that experience has shown that one small drop of N/100 iodine solution developes the starch color at once, in solutions of the volume and concentration described; and if N/1000 solutions be used, a perfectly definite, and not excessive allowance of $0{\cdot}1^{cc}$, equivalent only to 1/100 mg. of gold, is all that is needed.

Further, Rupp claims that the decomposition of aurous iodide is the greatest error of the process of Gooch and Morley, and refers to the handbooks of chemistry to substantiate this opinion. No handbooks are known to me which discuss the deportment of aurous iodide under exactly the conditions of this analytical process, but a study of the reaction, of which I made mention in a former paper,* showed that aurous iodide possesses stability sufficient for the purposes of the analytical process.

* Loc. cit.

I have, however, thought the matter of sufficient interest to warrant further investigation concerning the deportment of this salt under more varied conditions.

The method employed to determine the rapidity with which the aurous iodide decomposes was as follows: A measured quantity of a standard gold solution was drawn off into a beaker and diluted to the required volume. To this was added the necessary amount of a solution of pure and specially prepared potassium iodide, starch was added, and the freed iodine immediately treated with N/100 thiosulphate solution, but only to the rose tint, so that, as in the actual analysis, there might be no decomposing action due to an excess of thiosulphate upon the aurous salt.

The time was noted and the mixture allowed to stand until the iodine freed by the decomposition of the aurous iodide had brought the color of the liquid to an ordinary starch blue. The data obtained in this manner are shown in the following table. The gold solution used contained ·00048 g. of metal to the cubic centimeter.

No.	Gold grm.	KI grm.	Volume before the addition of thiosulphate. cm^3	Time in minutes necessary to give blue color.
1	0·0144	0·20	50	19
2	0·0144	0·20	50	47
3	0·0144	0·20	50	95
4	0·0144	0·20	50	150
5	0·0144	0·20	50	115
6	0·0144	0·20	50	82
7	0·0144	0·20	50	50
8	0·0096	0·08	50	17
9	0·0096	0·08	50	95
10	0·0096	0·08	50	28
11	0·0096	0·08	50	78
12	0·0096	0·08	50	18
13	0·0096	0·08	50	30
14	0·0096	0·08	50	36
15	0·0096	0.08	50	32
16	0·0048	0·05	50	45
17	0·0048	0·05	50	168
18	0·0048	0·05	50	25
19	0·0048	0·05	50	48
20	0·0048	0·05	50	43
21	0·0024	0·05	50	95
22	0·0024	0 05	50	105
23	0·0024	0·05	50	135
24	0·0024	0·05	50	none in 3 hours
25	0·0024	0·05	50	none in 3 hours
26	0·0014	0·01	35	130

It may be seen from these results that the decomposition of the aurous iodide under the conditions is comparatively slow, although potassium iodide was present in large excess. In these experiments the coloration ran through various gradations from pink to blue, as the starch used, in common with most specimens, had suffered hydrolytic change, the pink color indicating, of course,* the incipient excess of iodine, and not under-titration as Rupp has stated.

As I have previously shown, a complete determination by the method of Gooch and Morley can be easily accomplished in ten minutes; the maximum time actually necessary for the completion of the titration *after* the formation of the aurous iodide need not exceed four minutes. As can be seen from the experiments tabulated above, the minimum time required for the incipient decomposition of the aurous iodide was seventeen minutes. In no case did decomposition take place immediately, although potassium iodide was present in large excess. It is to be especially noted that these experiments begin where the analytical process ends, so that the probability of any iodine being freed by a too rapid decomposition is rendered yet more remote. The facts, then, afford absolutely no foundation for the statement that the decomposition of aurous iodide is an inherent source of error in the method of Gooch and Morley.

Concerning the accuracy of the method proposed by Rupp it is unnecessary to speak further, since Rupp now disputes the desirability of estimating less than the milligram; but to the reduction of gold chloride by arsenious oxide, the reaction used by Rupp, it is necessary to recur. Rupp states that the process of reduction goes on in acid solution. As I said in a former paper, I have been unable to effect the precipitation of the gold when free acid is present, but after the addition of acid potassium carbonate, reduction takes place. Rupp added to his solution of gold chloride containing hydrochloric acid, 10^{cm^3} of nearly N/2 solution of arsenious oxide. It is to be supposed that this solution of arsenious oxide was made, as usual, by dissolving the oxide in acid potassium carbonate. The question arises as to whether Rupp did not have enough acid carbonate in his arsenic solution to neutralize the free acid. The fact that the gold was precipitated, and within ten or fifteen minutes, points strongly, according to my experience, to an alkaline condition of the solution. So, if to heat a solution of acid potassium carbonate upon the water bath, under the experimental conditions, brings about the formation of an iodine-binding carbonate, and is indeed an error as Rupp says, it would seem that Rupp makes that error. But was it an error? It has seemed worth while to investigate this point.

* See Hale, this Journal (4), xiii, 390, 1902.

A N/10 arsenic solution was prepared as usual with the aid of 20 grams of potassium acid carbonate to the liter. Twenty-two cubic centimeters of this solution were drawn off and titrated with an approximately N/10 iodine solution in the usual manner. Four lots of this arsenic solution of 22$^{cm^3}$ each were then carefully drawn off and heated upon the steam bath for thirty minutes, and when cool were titrated against the above mentioned iodine solution. The volume of the solutions used in these experiments was in all cases approximately 75^{cc}. The results obtained are given in the accompanying table.

Standard As_2O_3 taken. cm^3.	Iodine used to titrate at once. cm^3.	Iodine used to titrate after heating ½ hour on the water bath. cm^3.
22·0	22·08	22·10
22·0	22·07	22·08
22·0	22·08	22·09
22·0	22·07	22·08

These figures show conclusively that acid potassium carbonate in solution of the concentration used in these experiments, 0·44 grms. in a volume of 75^{cc}, does not in thirty minutes heating upon the water bath undergo such change as to cause it to absorb an appreciable amount of iodine in the following titration. Just what the effect may have been in Rupp's experiments cannot of course be determined in the absence of knowledge in regard to the acidity of his gold solution, and the alkalinity of his arsenic solution.

In conclusion it is obvious that the criticisms made by Rupp are not warranted by the facts. While, as its author now concedes, the method proposed by Rupp is not to be considered of value for the determination of small amounts of gold, all the evidence goes to show that the process of Gooch and Morley is accurate, and in the hands of a skillful analyst, adapted to the estimation of minute quantities of gold.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Hydrates in Solution.* — It has been known for some time that many inorganic salts give abnormal results in the lowering of the freezing points of their comparatively concentrated aqueous solutions. They show in dilute solutions depressions of the freezing point which correspond to their ionization as determined by electrical conductivity, but when a certain degree of concentration has been reached the depression of the freezing point is abnormally great in most cases. H. C. Jones and his co-workers have made an extensive study of this matter, and it has been found that all but nine of the forty-nine substances experimented upon showed a minimum in the freezing-point curve; that is, the effect of the substance in lowering the freezing point gradually diminished as the concentration increased—on account of diminished ionization—and then the abnormal increase of effect occurred to such an extent that the curve showed a minimum point. Even where the freezing-point curves did not show a minimum, there was an abnormal depression of the freezing point in nearly every case with concentrated solutions. It was found also that those substances which crystallize out of solution with the larger number of molecules of water of crystallization give the greatest molecular lowerings of the freezing point of water in concentrated solutions. The boiling-point curves, as far as they have been worked out, also show a minimum, but this occurs at a greater concentration than in the corresponding freezing-point curve.

From the results of this work, the important conclusion is reached that in concentrated solutions a part of the solvent is combined with the dissolved substance, and such solutions are, therefore, more concentrated than they would appear from the amount of dissolved substance present in them. This view explains the abnormal behavior of concentrated solutions in a very simple and satisfactory way; for it is difficult to imagine that substances should crystallize with water of crystallization, unless they were capable of combining with this water while in solution. If further work confirms this new explanation, a serious objection to the ionic theory of solutions will be removed.—(Jones and Getman) *Amer. Chem. Jour.*, xxxi, 303. H. L. W.

2. *A Microscopical Method of Determining Molecular Weights.*—This interesting method, described by George Barger, of King's College, Cambridge, England, depends upon the increase or decrease in size of alternate drops of two solutions in a closed capillary tube. One of the solutions is prepared from a substance of known molecular weight, while the other contains a known amount of the substance whose molecular weight is to be determined. When the two solutions contain the same number of molecules in a given volume, the vapor tensions will be equal and

the drops will not change in size, but if one of the solutions is stronger in this respect, its drops will increase in size at the expense of the other. The method then consists in finding a known solution of the same vapor tension as the known one by microscopic measurement of the drops. It is not necessary that the solvent used should have a constant melting point or a constant boiling point, hence impure solvents, such as ether saturated with water, 90 per cent alcohol or 80 per cent acetic acid can be used successfully. The solvent should not be too volatile, on account of the difficulty of manipulation, and, on the other hand, if the solvent is not sufficiently volatile, the experiment takes too long. The details in regard to the application of the method need not be given here, but it may be observed that the process has been tested with a great variety of substances with satisfactory results.—*Jour. Chem. Soc.*, lxxxv, 286. H. L. W.

3. *Rubidium-Mercuric Double Salts.* — GROSSMANN has prepared the double salts

$$2RbI \cdot HgI_2,$$
$$RbI \cdot HgI_2,$$
$$2RbSCN \cdot Hg(SCN)_2,$$
and
$$RbSCN \cdot HgSCN,$$

and also a pyridinium-mercuric cyanide-thiocyanate,

$$(C_5H_6N)SCN \cdot Hg(CN)_2.$$

From these results it appears that rubidium iodide forms a much less extensive series of double salts with mercuric iodide than is the case with cæsium iodide, for with the latter five double salts are known. The double thiocyanates under consideration correspond exactly to the cæsium-mercuric salts described by Wells and Bristol, except that one of the latter, $2CsSCN \cdot Hg(SCN)_2 \cdot H_2O$, contains water; hence there is no evidence in this case of a more extensive series of salts with cæsium than with rubidium. The pyridine compound is an example of the combination of mercuric cyanide with many kinds of salts.—*Berichte*, xxxvii, 1258. H. L. W.

4. *Zirconium Tetra-iodide.* — By acting upon metallic zirconium or upon zirconium carbide with hydrogen iodide at elevated temperatures, STÄHLER and DENK have obtained the tetra-iodide ZrI_4 in the form of a sublimate, consisting of a reddish brown, crystalline powder which fumes strongly in the air and reacts violently with water and acids. This substance is entirely different from the product, supposed to be this compound, obtained by Dennis and Spencer several years ago, which consisted of white crystals that were not decomposed by water or dilute acids. It appears, from the close analogy known to exist between the compounds of titanium and zirconium, that the composition of the white compound was incorrectly determined.—*Berichte*, xxxvii, 1135. H. L. W.

5. *Use of the Thermal Junction in the Ultra-Violet.* — A. PFLÜGER shows that it is possible to detect the heat of spectral lines in the extreme ultra-violet by means of a Ruben's thermal junction and the throw of a delicate galvanometer. The strong lines of cadmium, zinc, aluminium, etc., gave deflections of many hundred scale divisions, and even the finer lines of these metals gave deflections from 20 to 100 scale divisions.

It is shown that the energy distribution in these ultra-violet lines of the metals, with the exception of magnesium and iron, is strongest below wave length 260$\mu\mu$, and in a region where the ordinary photographic plate fails to register. The aluminium line at 186$\mu\mu$ shows a very strong energy radiation. The author found it useful to use single breaks of the primary circuit and to notice the first deflection of the galvanometer. The thermal junction was enclosed in a vacuum to avoid currents of air. The table of distribution of energy in the spark spectra of metals shows that the energy of radiation of the ultra-violet lines is in general far greater than the ultra-red lines. At first a quartz spectrograph was used, later a Rowland grating ruled on a fluor spar plate. Schumann's very short wave lengths also gave deflections with the thermal junction.—*Ann. der Physik*, No. 5, 1904, pp. 890–918. J. T.

6. *Internal Friction of Nitrogen.*—It is proved in the molecular theory of gases that the internal friction is independent of the density. Prof. S. W. HOLMAN has shown that the dependence of the viscosity upon temperature cannot be represented by a function of the absolute temperature with constant exponent, but that it increases the more slowly with the temperature the higher this latter is. In order to retain the theory of elastic spheres, STEFAN imagines that the mean free wave lengths at equal pressures increase with the temperature and the size of the molecule at the same time diminishes. One cannot at present verify this hypothesis by calculation. SUTHERLAND supposes a change in the attraction between the molecules is modified by a rate of collision, and he arrived at a formula which expressed under this hypothesis the ratio of the frictional coefficients at any two temperatures. A. BESTELMEYER takes up the measurement of the internal friction of nitrogen, according to the method used by Holman and arrives at the result that Sunderland's formula represents with great approximation the internal friction of nitrogen between 300° and −190°. The departure from the law at the temperature of liquid air indicates the beginning of a greater friction at lower temperatures.—*Ann. der Physik*, No. 5, 1904, pp. 944–995. J. T.

7. *Damping of Electrical Oscillations.* — The resistance of the electric spark assumes considerable importance in the subject of wireless telegraphy. The resistance is variously extended by different observers. BJERKNES estimates it at 11 ohms. BRAUN as 0·1 ohm. K. SIMONS measures the amplitude of electrical waves damped by spark gaps of increasing lengths, and concludes

that the resistance of a spark gap is so much the smaller, the greater the quantity of electricity in the discharge, and that within the limits of his observation the resistance of the spark gap increased with the length.—*Ann. der Physik*, No. 5, 1904, pp. 1044–1053. J. T.

8. *On the Compressibility of Solids;** by J. Y. BUCHANAN, F.R.S.—The author has carried on a series of careful experiments for the determination of the absolute linear compressibilities, from pressures of 200–300 atmospheres, and at temperatures between 7 and 11° Centigrade, of the metals platinum, gold, copper, aluminium and magnesium. The method employed is that used by the author in determining the compressibility of glass in 1880, and developed earlier in connection with the deep-sea soundings made by the Challenger Expedition in 1875. Briefly stated, this method consisted in the use of a solid piezometer in which the rod of the glass to be experimented upon (57^{cms} in length) was inserted in a closely fitting tube of the same material; the two were fused at one end and at the other there was an empty space of some 3^{cms} between the end of the rod and that of the tube; a steel thermometer index was inserted at the end of the rod and the tube then sealed.

"Before the instrument was attached to the sounding line, the index was brought down by means of a magnet to rest on the end of the internal glass wire, exactly in the same way as if it had been the mercury column in a *maximum* and *minimum* thermometer. The instrument was then sent to the bottom, or to whatever depth might be decided on. During the descent the temperature of the glass, both inside and outside, fell with that of the water through which it passed, but as the contraction produced was the same on the wire and on the tube, there was no differential effect to be recorded by the index. On the other hand, the increasing pressure, as the instrument descended, affected only the outside tube, which it shortened. In contracting, it was obliged to pass the index, which was kept in its place by the internal wire. When the instrument was being hove up, the reverse process took place; the tube lengthened, and lifted the index clear of the internal wire by an amount equal to the lengthening of that portion of the tube. As the whole clearance produced by the expansion from the greatest depth did not exceed 1mm., its amount had to be estimated by the eye with the assistance of a magnifying glass."

The instrument of precision constructed in 1880 on the basis of the Challenger observations was essentially the same as that employed in the present research. The various parts of the latter instrument were made, however, of steel. The metals experimented upon were in the form of rods or wires and fitted into steel tubes passing into a central steel block. The ends of the rod or wire were closed with thick glass tubes kept in their places by open

* Read before the Royal Society of London, Feb. 25, 1904; from an advanced proof sent by the author.

steel caps; each tube was observed by a microscope with micrometer eye-piece. Details in regard to arrangements of the parts, the manometer employed, etc., will be found in the original paper. In regard to the progress of an experiment the author remarks:

"The effect observed and measured is the lengthening of the rod when the pressure is relieved. As the compressibility of solids is very small the highest pressures have been used which were found to be compatible with the reasonable persistence of the glass terminals; the usual pressure was in the neighbourhood of 200 atmospheres. Very few of the glass terminals stood over 300 atmospheres. The pressures actually chosen were as nearly as possible those at which the manometer had been compared with the 'Challenger' piezometer. The body under observation is in the form either of a rod or a wire. If it is in the form of a rod then it is fitted with wire ends of sufficiently small calibre to enable them to enter the glass terminals. During an experiment with a rod it contracts while the pressure is being raised, and expands again when the pressure is relieved. The steel tube which holds it, however, acts in the opposite sense: it expands while the pressure rises and contracts while it falls. If the two surfaces were perfectly smooth, one half of the change of length would be measured at the one end and the other half at the other end. As the surfaces are not perfectly smooth, this does not usually occur. Moreover the steel tubes are prolongations of the central steel block which holds them. The block is bored with holes at right angles to each other in the three principal directions. Consequently for a distance of about an inch and a half in passing through the block the rod is not supported at all. With the exception of this small portion, however, the rod is supported throughout the whole of its length by the steel tube. Now, although it is thus nominally supported equally throughout the whole of its length. we know that in reality this is pretty certain not to be the case. At some place, either in the right arm or in the left arm of the apparatus, the rod is sure to bear more heavily than in any other part. The contraction under pressure and the expansion under relief of pressure will then apparently take place as from this point as origin. Supposing this point itself to be motionless it is evident that the change of length measured at the two ends will be in the same proportion to each other as would be the arcs which they would describe if the rod were a lever oscillating on the point as a fulcrum. As there is no support at all at the centre this point must lie on one side or on the other of it and the motions of the ends must be unequal. But the fixed point of the tubular receiver is the central block; therefore any point in, let us say, the right-hand tube will, when pressure is being raised, move to the right, and on relief of pressure, retreat by an equal amount to the left. Consequently when we observe and measure the change of position of, for instance, the right-hand extremity

of the rod, when the pressure is relieved, that change of position is composed of two motions, the expansion of the part of the rod which lies between the right-hand extremity and the point in it whose motion with respect to the steel carrying tube is nil, along with the proper motion of that point. Similarly, when we measure the change of position of the left-hand end, it also is composed of two parts, the expansion of the part of the rod which lies between the left-hand extremity and the same point in the length of the rod where its motion with respect to the steel tube is nil, along with the proper motion of that point. But at the left-hand end the motion of expansion is to the left, and at the right-hand end it is to the right, while the proper motion of the position of the common point on the rod and on the tube is always in one direction, and in this case, to the left. Therefore the distance measured in the right-hand microscope is the expansion of the portion of the rod which lies to the right of the point on it which is motionless relatively to the tube *minus* the proper motion of this point: and the distance measured at the left-hand end is the expansion of the remainder of the rod *plus* the proper motion of the common point. Consequently the algebraic sum of the two motions measured is the expansion of the rod under the relief of pressure."

The following table gives a summary of the results obtained which are stated in full in six tables preceding. This final table is as follows:

Substance.	Year.	Atomic weight.	Density.	Compressibility.	
				Linear.	Cubic.
Platinum	1904	194	21·5	0·1835	0·5505
Gold	"	197	19·3	0·260	0·780
Copper	"	63	8·9	0·288	0·864
Aluminium	"	27	2·6	0·558	0·1674
Magnesium	"	24	1·75	1·054	3·162
Mercury	1875	200	13·6	1·33	3·99
Glass, flint	1880	---	..	0·973	2·92
" "	1904	---	2·968	1·02	3·06
" German ..	"	---	2·494	0·846	2·54

"In this summary the compressibilities of English flint glass and of the glass of which ordinary German tubing is made as well as that of mercury have been included for purposes of comparison. The compressibility of mercury rests upon a large number of observations made in the 'Challenger,' by which its apparent cubic compressibility was found to be 1·5 per million per atmosphere."

The author calls attention to the relation existing between compressibility and density, and remarks that a field for interesting research is here opened in which the method is capable of great refinement.

II. Geology and Natural History.

1. *United States Geological Survey.*—The following publications have been recently issued :

Folio No. 102. Indiana Folio, Pennsylvania ; by George B. Richardson. The Indiana quadrangle is made up of Carboniferous strata nearly all belonging to the Pennsylvanian series and containing workable beds of coal (Freeport). The two characteristic plains of the Allegheny Plateaus are almost unrecognizable in this part of Pennsylvania. The geologist will note the omission of structure sections.

No. 103. Nampa Folio, Idaho-Oregon ; by Waldemar Lindgren and N. F. Drake. The geological map of the Nampa quadrangle shows wide areas of dissected Tertiary lake beds together with extensive Quaternary gravels and recent flood plains. Tertiary basalt and rhyolite and Quaternary basalt occupy smaller areas. The lake beds of the Payette and Idaho formations once covered the whole district and this folio is in particular a study of the geographical conditions during the formation and partial destruction of beds of sand, gravel and clay with a thickness of 200 to 1000 feet. The characteristics of stream beds in arid regions are well shown by the Payette, Boise and Snake rivers.

No. 104. Silver City Folio, Idaho ; by Waldemar Lindgren and N. F. Drake. With the exception of Cretaceous? granite, the formations represented on the Silver City quadrangle are Eocene, Pliocene and Quaternary. An early Tertiary epoch of erosion was followed by outbursts of rhyolite and basalt and the deposition of the Payette lake beds to a thickness of 2000 feet. A short period of erosion enabled the streams to cut to their present levels. The Idaho formation was deposited in the waters of a shallow lake during Pliocene time. The Snake River Canyon was cut during Miocene. Glassy basalts form the highest Tertiary beds and may have extended into the Quaternary. Terraces show the gradually deepening channel of the Snake River. The ore deposits at Silver City are fissure veins of post-Eocene age and cut through granite, rhyolite and basalt. Opals occur in vesicular cavities in the rhyolite and basalts.

No. 105. Patoka Folio, Indiana-Illinois ; by Myron L. Fuller and Frederick G. Clapp. Carboniferous strata of the Pennsylvanian series containing minor veins of coal are exposed in a small portion of the Patoka quadrangle. The most prominent and widespread formations are the glacial drift and the Wabash flood plains. The Illinoian stage is represented by an extensive series of lake deposits, gravel plains and ridges, and till sheets. The Iowan stage is represented by marl loess, while of the Wisconsin stage there remain small areas of dunes and terraces. The mineral resources of this region are coals and clays. Much valuable land has been reclaimed by draining and diking.

Bulletin No. 225. Contributions to Economic Geology, 1903.

S. F. EMMONS, C. W. HAYES, Geologists in charge. 527 pp. This report contains a series of fifty-one contributions from thirty-seven members of the Survey who have been engaged chiefly in economic work during the year. Brief introductory statements are also given on the investigation of metalliferous ores by S. F. Emmons and of non-metalliferous economic minerals by C. W. Hayes.

2. *The Atoll of Funafuti. Borings into a Coral Reef and the Results.* xiv + 428 pp., 6 pls., 69 figs. with 21 charts and geological maps. Published by the Royal Society.—Darwin believed that the history and origin of coral reefs must remain uncertain until a drill core could be obtained for a depth of at least 600 feet. Under the lead of Professor SOLLAS the Royal Society undertook to carry out this suggestion, and a committee, with Professor T. G. Bonney as chairman, was appointed to have general supervision of the project. Few scientific expeditions can match the Funafuti undertaking in determination and thoroughness. In 1896 Professor Sollas failed to attain a greater depth than 105 feet. The expedition of that year resulted, however, in valuable collections and in the construction of the most accurate and detailed chart yet made of an atoll. A study of the surface features and of the changes in elevation was made but few conclusions of general application were reached. Meteorological observations and magnetic surveys were also made. The expedition of 1897 resulted in a drill hole 698 feet deep, but was unsatisfactory owing to the small amount of solid core obtained. A detailed geological survey was, however, made of the atoll by Professor DAVID and Mr. SWEET. The third expedition, in 1898, succeeded in driving the boring down to 1114½ feet and obtaining about 384 feet of solid core. A hole was also bored into the lagoon to a depth of 245 feet. Slices for microscopic examination were taken longitudinally from the middle of each piece of rock. The core proved that the atoll was formed from the surface to the bottom of the bore of calcareous rock, chiefly composed of *Lithothamnion* and *Halimeda* as well as of reef-building corals. The lower part of the core seemed like a consolidated chalky ooze but was determined to be coral material converted into dolomite. A collection of living organisms on the seaward slope of the lagoon down to 200 fathoms was made for comparison with the dead organisms of the core rock. Professor David finds that the original foundation of the atoll is probably volcanic, that its shape has been modified by organic growth, winds and currents, that it is slowly enlarging its periphery, and that several oscillatory vertical movements of the shore have taken place in the immediate past. The Biology of the Reef-forming Organisms is discussed by A. E. FINCKH (pp. 125–150). Arranged in order of importance, Mr. Finckh describes the distribution, mode of occurrence, etc., of *Lithothamnion*, *Halimeda*, *Foraminifera*, *Corals.* Observations on the growth of reef-building organisms showed interesting results. For instance,

a mass of Halimeda increased 2¼ inches in height and 3¼ inches in thickness in six weeks! The drill cores were sent from Funafuti to England and were examined in microscopic sections by Professor JUDD and Dr. HINDE (pp. 167–361). The quantity of calcareous algæ is surprisingly large. Oolitic structure and stratification are absent and there is no admixture of deep water organisms, the same genera and species occur from top to bottom of the section. Extensive chemical and mineralogical changes have taken place in the rock since the corals were living, and these changes have been studied in detail by Professor Judd and Dr. CULLIS.

The reviewer is disappointed to find no discussion of the origin of coral reefs as illustrated by this typical atoll, yet the conclusion seems unavoidable that subsidence has been the chief cause of growth of the reef in this case. The workers in the Funafuti project deserve high praise for the conception of the scheme, for its successful execution under discouraging circumstances, and for the valuable scientific results obtained.

3. *A Revision of the Paleozoic Bryozoa;* by E. O. ULRICH and R. S. BASSLER. *Part 1. On the Genera and Species of Ctenostomata.* Reprinted from the Smithsonian Collections (Quarterly Issue) vol. 45, published April 11, 1904.—In this first part of the much needed revision of the Paleozoic Bryozoa, the authors discuss all the known species which can be referred to the order Ctenostomata. While the rather peculiar fossils so classified can not be proved to belong to this order, most of whose members are living species, the evidence seems to point strongly in that direction. The greatest objection is that the zoaria of the recent species are horny or membranaceous, while those of the Paleozoic forms were sufficiently calcareous to be preserved. The species, which number thirty-three, are arranged under five genera and three families: the Rhopalonariidæ (*Rhopalonaria*), the Vinellidæ, new family, (*Vinella*, *Heteronema*, gen. nov. *Allonema* gen. nov,), and the Ascodictyonidæ (*Ascodictyon*). It will be noticed that the family Ascodictyonidæ is here restricted to the typical genus and *Vinella* removed to a new family erected to include it and its allies. It is to be regretted that the authors have seen fit to insert here descriptions of a new genus and two new species, *Heteronema? contextum* sp. nov. and *Ptychocladia agellus* gen. et sp. nov. which are of so problematical a nature that they admit that the one may be a sponge and the other an alga or some peculiar type of Foraminifera. While there is reason for publishing descriptions of such peculiar organisms in order to get the opinion of other writers on the subject, it does not seem desirable to give new names, particularly new generic names, to fossils whose characters are so obscure that they cannot be definitely referred to any class or even kingdom. It is better to await the discovery of good material, as publication at this time only invites further revision. In addition to the description of the species, the paper

gives a good summary of the literature, and is well illustrated by four plates containing many figures of recent and Paleozoic Ctenostomata. P. E. R.

4. *An attempt to Classify Paleozoic Batrachian Footprints.* Trans. Roy. Soc. Can., 2d ser. vol. ix, Sec. IV, p. 109, 1903. *New Genera of Batrachian Footprints of the Carboniferous System in Eastern Canada.* Can. Rec. Sci., vol. ix, No. 2, p. 99, 1903; by G. F. MATTHEW, LL.D.—These articles are complementary to each other. The first takes a wider field of view than the second, viz.: the described Carboniferous tracks of America, supposed to have been made by Batrachian animals, and is an endeavor to classify these footprints according to their forms, and the number of toes represented. The author does not think the presence or absence of a tail mark or central groove between the rows of footmarks of the right and left limbs of general classificatory value, as some tracks which are closely alike in other respects are distinguished mostly by this marking; and the "tail mark" may be absent from one part of a trail and present in another.

A table is given at page 111 of the first paper in which the tracks of the Lower Carboniferous and the Coal Measures are arranged according to the number and the weight of the toe-impressions, etc.

Plates show some of these characteristic tracks, and give figures of new genera proposed. It is stated that no European footprints of Carboniferous age were considered in this classification and description of American forms.

5. *Geology;* by THOMAS C. CHAMBERLIN and ROLLIN D. SALISBURY. In two volumes. Vol. I, Geologic Processes and their Results. xix and 654 pp., 24 pls., with three tables of water analyses. New York, 1904 (Henry Holt & Company).—This volume, printed in clear type upon a heavy grade of paper, illustrated by numerous original drawings and photographs, both well selected and reproduced, possesses a distinctive character and fills a place not quite occupied by any other manual. The methods of treatment, as stated in the preface, bring especially to the front the methods of action and developmental aspects of the geologic agencies. Careful distinctions are drawn between those principles well founded on observed facts and others which have usually been as commonly accepted but which ultimately depend upon hypotheses as to the origin or internal nature of the earth. In the less certain departments of geological knowledge the method of multiple or alternative hypotheses is developed and the student shown the limitations of present real knowledge upon the subject. The first chapter consists of a preliminary outline on the field of geology, following which are chapters upon the work of the atmosphere, of surface and underground water, of snow and ice, structural geology, movements and deformations of the earth's body, extrusive processes and the geologic functions of life. The reputation of the authors in their several specialties is a sufficient

guarantee as to the depth and thoroughness of treatment, while in the chapter on the "Origin and Descent of Rocks," in which is presented an outline of the recently proposed quantitative system of classification, the authors have had the assistance of Prof. J. P. Iddings.

In the reviewer's opinion, the volume hardly supplants the manuals at present in use but rather supplements them, and from the somewhat philosophic and evolutionary cast would be most profitable to the student who has previously accumulated sufficient facts to feel the need of their coördination. It will be of chief value, therefore, to advanced students, to geological specialists, enabling them to get comprehensive outlooks over related fields, and to teachers of geology in general. The character of the volume should make it attractive also to the general reader of scientific tastes who wishes to follow the latest trends of geologic thought. J. B.

6. *The Mineral Resources of the United States for the Calendar year 1902;* DAVID T. DAY, Chief of Division of Mining and Mineral Resources. Pp. 1038, 8vo. U. S. Geological Survey, Washington.—This is the Nineteenth Annual Report of the series, and is in the octavo form which is most convenient for use. It gives the usual summary of the mineral production for the year, with detailed papers on specific subjects by different authors. The system now adopted of distributing the individual chapters in advance of the final volume, whenever such are ready, has the great advantage of bringing the material within reach of the public very promptly, while the complete volume issued later is invaluable for reference.

7. *Fragmenta Florae Philippinae;* by J. PERKINS, Ph.D. Fascic. 1; 66 pages imp. 8vo, Leipzig, 1904 (Gebrüder Borntraeger, price 4 marks).—Even before the pacification of the Philippines various projects were formed by Americans for the scientific investigation of the Islands. It was felt that the American occupation of this biologically rich archipelago not only offered to our investigators new opportunities but in a way imposed upon them certain obligations toward activity in the fresh field thus unexpectedly opened. In their enthusiasm some of those most eager to undertake this task little appreciated its difficulty. Biological areas are not changed by shifting political boundaries. The Philippines are and must always remain a part of the Old World. We have not in all America adequate literature or authentic specimens for a scholarly examination of the Philippine flora. To accumulate such material must be a matter of years of patient and critical labor. It is true that American energy, backed by the liberal support of the United States government, as well as by private patrons of science, could speedily bring together in our country Philippine collections more extensive than any which have resulted from the slower methods of Spanish or other foreign explorers, yet this is by no means sufficient. The Philippine flora possesses such a strong affinity with

the vegetation of the other Australasian islands, and, indeed, with that of continental India, that it can be studied intelligently only through comparison with types in foreign herbaria and by investigators familiar with Old World floras.

Under these circumstances, it was a wise decision of the Carnegie Institution to make a grant, not for the investigation of the Philippine flora in America, but to aid Dr. Janet Perkins in studying the subject in Berlin, where with access to numerous Old World types and with the counsel and collaboration of highly trained specialists on the Asiatic and Australasian floras, the work could be carried on in a far more scholarly manner. It is accordingly with great regret that we learn that this grant of the Carnegie Institution has not been renewed after the first year. Dr. Perkins, however, has continued her examination of the Philippine flora and a substantial installment of the results is now at hand.

The body of the present paper is occupied by an "Enumeration of some of the recently collected plants of Ahern, Jagor, Lober, Merrill, Warburg and others." In this copiously annotated list, including many diagnoses of new species and much critical synonymy, the *Leguminosae*, *Dipterocarpaceae*, *Anacardiaceae*, *Meliaceae*, *Pinaceae*, and *Taxaceae* have been treated by Miss Perkins herself, the *Symplocaceae* by Brand, *Acanthaceae* by Lindau, *Fagaceae* by von Seemen, *Typhaceae* by Graebner, *Orchidaceae* by Schlechter, *Palmae* by Beccari, *Myristicaceae*, *Pandanaceae*, and *Begoniaceae* by Warburg, and *Sapindaceae* by Radlkofer,—names which amply attest the critical nature of the work.

In a paper of such composite authorship uniformity can scarcely be expected, yet it is to be regretted that the diagnoses are partly in Latin and partly in English, and that the arrangement of the families is quite arbitrary, which in a publication as yet unindexed gives needless difficulty of reference. Among the plants discussed those of Mr. E. D. Merrill and of Dr. O. Warburg are the most numerous and interesting. It is to be hoped that Dr. Perkins may receive the encouragement and facilities in the continuance of her work which its scientific value so richly merits.

B. L. R.

8. *Botanical Publications by the Bureau of Government Laboratories at Manila.*—A series of pamphlets are being issued from time to time, under the auspices of the Department of the Interior, from the Government Laboratories in Manila, of which Mr. Paul C. Freer is Superintendent. Among these we note Nos. 6, 7 and 8, recently distributed, upon botanical subjects. No. 6 (36 pp.), by Elmer D. Merrill, describes new and noteworthy Philippine plants, and also discusses the American element in the Philippine flora. No. 7 (43 pp.), by Penoyer L. Sherman, Jr., discusses the gutta percha and rubber of the Islands, describing the various species and giving their distribution, with a map and numerous illustrations. Suggestions are made in regard to the

prospect not only of utilizing the natural supply, but also of introducing and cultivating foreign species.

No. 8 (193 pp.), by Elmer D. Merrill, gives a Dictionary of the plant names of the Islands with the botanical equivalents. There are two parts, in the first of which the local names and in the second the botanical names are made the basis of the alphabetical arrangement.

III. Miscellaneous Scientific Intelligence.

1. *Wilhelm Ostwald;* by P. Walden. 8vo, pp. 120. Leipzig, 1904 (W. Engelmann, price 4 marks). — Last December the friends and former students of Wilhelm Ostwald celebrated in Leipsic the twenty-fifth year of his doctorate. A special volume of the Zeitschrift für physikalische Chemie was issued on the occasion, and an account of Ostwald's life and work up to the present time. The volume of the Zeitschrift, containing nearly nine hundred pages, consists of contributions in German, English, and French from over thirty of his former students, coming from eight different countries.

Walden's account of Ostwald's life and work is exceedingly interesting and is told in a most entertaining manner. He was well qualified to undertake the work as he studied with Ostwald and is professor at Riga, where Ostwald was born and where he was professor for six years.

Ostwald was born in 1853, and as a boy and when first a student at Dorpat he was not particularly forward in his studies. When once started on his profession, however, his progress was extraordinary. After taking his doctor's degree in December, 1878, he immediately became an instructor in Dorpat. Two years later, in 1881, he was called to Riga as professor of chemistry, where he remained till 1887, and here in 1886 he received his first foreign student, S. Arrhenius, who proposed the theory of electrolytic dissociation the following year. He became professor of physical chemistry in Leipsic in 1887, a position which he still holds.

The first volume of his great 'Lehrbuch der allgemeinen Chemie' appeared in 1885 and from that time forward his literary work has been prodigious. He has written over twenty volumes representing fifteen thousand pages, besides several thousand reviews of scientific investigations and books. The Zeitschrift was started chiefly by him in 1887 and he has been one of the editors ever since.

As a teacher, he has been remarkably successful. His laboratory at Leipsic has been the center for physical chemistry since he took charge, and almost every branch of the subject has received its share of attention. Students have come to him from every civilized country. At the same time, he has carried on many investigations of his own. H. W. F.

2. *Changes in the Transparency of the Earth's Atmosphere.*—A circular letter has been issued, under the auspices of the U. S. Weather Bureau, having as its object the accumulation of data bearing upon the general diminution in the transparency of the earth's atmosphere noted by various observers during 1902, but which disappeared in 1903. Records are asked for "that will assist in defining the dates of beginning and ending, and the extent of this change in transparency. Such records may consist of photometric or photographic observations of the brightness of the stars; changes in the solar or stellar spectra; unusual prevalence of halos, large Bishop's ring, or haze; observations of heat received from the sun, as made with actinometers or pyrheliometers; observations of the polarization of the blue sky light and of scintillation of the stars. Undoubtedly this diminution and increase of transparency began and ended at different dates in different places, as the phenomena spread gradually over the world during the years 1902 and 1903; additional records are, therefore, desired in order to trace its progress."

Facts bearing upon this subject may be forwarded to Professor Cleveland Abbe at Washington, by whom the circular is signed.

3. *The Alpheus Hyatt Memorial Fund for Field Lessons.*—The report recently issued by the Trustees of the Hyatt Memorial Fund at Boston gives an interesting summary of the field work accomplished during the first year since the organization began. Superintendent Seaver states that 26 teachers from 9 schools have profited by the income of the fund and 2308 children have been taken to the seashore and country. The value of such field work as a part of the education of school children is obvious and it is gratifying to note that the money available produces so large a return. Contributions are asked for in order to increase the endowment; they may be sent to Mr. Stephen H. Williams, 24 Milk st., Boston.

4. *Altitudes in the Dominion of Canada;* by JAMES WHITE, Geographer. Geol. Survey of Canada, Ottawa, 258 pp.—Since 1894 Mr. White has been collecting and classifying data regarding elevations in Canada. Altitudes are given along railroads, rivers and in detail about the Great Lakes and the St. Lawrence. The present volume is the only publication containing this mass of fact and thus becomes a necessary reference book. Four profiles and a relief map of North America accompany the volume.

5. *Publication of the Earthquake Investigation Committee in Foreign Languages.* No. 15. Pp. 72 with eight plates. Tokyo, 1904.—This number is devoted to a discussion by F. OMORI of the application of seismographs to the measurement of the vibration of railway carriages. It gives a detailed account of a series of practical experiments made upon the Government railways of Japan under varying conditions.

6. *Clarkson Bulletin, Vol. I, No. 2,* April, 1904. — This bulletin contains the announcement of the Clarkson School of Technology at Potsdam, N. Y., established in 1896. The second summer session begins July 6, 1904, and extends for six weeks.

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* This Index contains the general heads, BOTANY, CHEMISTRY (incl. chem. physics), GEOLOGY, MINERALS, OBITUARY, ROCKS, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

THE

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. I.—*Atmospheric Radio-activity;* by H. A. Bumstead.

It has recently been shown by a number of investigations, made in widely separated localities, that the radio-active gas obtained from the earth, from water, and from petroleum, has the same properties as the emanation from radium.* Some of the emanation must of course be present also in the air aboveground, and it is an immediate inference that the radio-active phenomena of the atmosphere may be due to its presence. Thus one might expect that the activity deposited upon a negatively-charged wire when it is exposed in the open air would decay at the same rate as the excited activity due to radium, and Elster and Geitel have recently made some measurements† which confirm this expectation, at least approximately. On the other hand, Rutherford and Allan,‡ who were the first to investigate carefully the rate of decay of the negatively-charged wire, obtained a different result; they found that the activity falls off regularly according to an exponential law and reaches half-value in about 45 minutes, whereas the radium-induced activity does not fall off exponentially during the first two hours, and, when it does begin to do so, its half-value time is 28 minutes instead of 45. Quite recently, Allan has made an extended study of atmospheric radio-activity§ in the course of which he has, in the main, confirmed the previous results obtained by Rutherford and himself with regard to the rate of decay, although certain observations point to the conclusion that the decay is not entirely regular.

* Adams, Phil. Mag., Nov. 1903; Elster and Geitel, Phys. Zeitschr., v, p. 11, 1904; Bumstead and Wheeler, this Journal, Feb. 1904; Himstedt, Drud. Ann., xiii, p. 573, 1904.
† Elster and Geitel, loc. cit.
‡ Rutherford and Allan, Phil. Mag., Dec. 1902.
§ Allan, Phil. Mag., Feb. 1904.

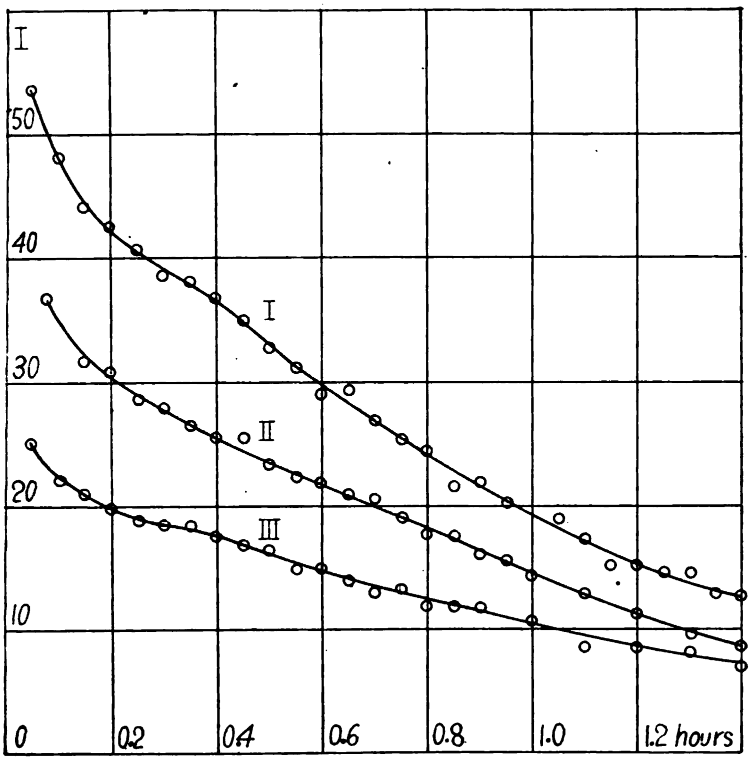
The experiments which I am about to describe were begun before the appearance of the recent papers by Elster and Geitel and by Allan, and were continued in view of the discrepancy between their results, and also because indications had been obtained of results not observed by either. A fine copper wire $\frac{1}{4}^{mm}$ in diameter was suspended horizontally, about 8 meters above the ground, between two neighboring buildings; it was attached to the negative pole of a Wimshurst machine, driven by a small motor, the positive pole of the Wimshurst being earthed. A parallel spark-gap 5^{mm} long served to keep the potential-difference constant during an exposure which was usually continued for three hours. The activity of the wire was observed in a cylindrical testing vessel, with the central rod connected to one pair of quadrants of an electrometer; the rod was protected by an earthed guard-plate in the usual manner. The bottom of the testing vessel was easily removable and bore four vertical brass rods just within the walls of the cylinder, and about these rods the exposed wire could be wound. The electrometer was of special construction, with sulphur insulation and adjustable quadrants; the needle was of silvered paper and the suspension a quartz fiber dipped in a solution of calcium chloride to render it conducting, as in Dolezalek's electrometer. With the suspension used and 90 volts on the needle, the sensitiveness was sufficient (250^{cm} per volt with the scale at one meter), and the instrument was very steady. When the potential on the needle was kept constant, the sensitiveness of the apparatus to a small sample of uranium oxide did not vary appreciably over a period of several days. Accidental motions of the needle were largely avoided by enclosing the connecting wire between electrometer and cylinder in an earthed brass box, outside of which a small electromagnet served to insulate or short circuit the quadrants.* The exposed wire could be put into the cylinder without disturbing the connections or jarring the electrometer, so that readings could be begun immediately; the only time lost after the end of the exposure was in taking in the wire and winding it about the frame. After the wire had been put into the testing vessel, measurements of the ionization current were made at intervals of three minutes during the first part of the experiment when the change in activity was rapid; later, readings were taken every six minutes.

In the earlier experiments, comparatively short wires were exposed (5 meters) and the decay of the activity of these could be followed with some accuracy for about two hours. The similarity to the behavior of the excited activity due to radium

* This arrangement has been previously described. This Journal, Feb. 1904, p. 100.

was unmistakable and is clearly shown in the curves plotted in fig. 1. The upper and lower curves, I and III, represent the decay of the activity of wires exposed in the open air on different days, while the curve between them, II, was obtained with a wire which had been exposed in a two-liter flask con-

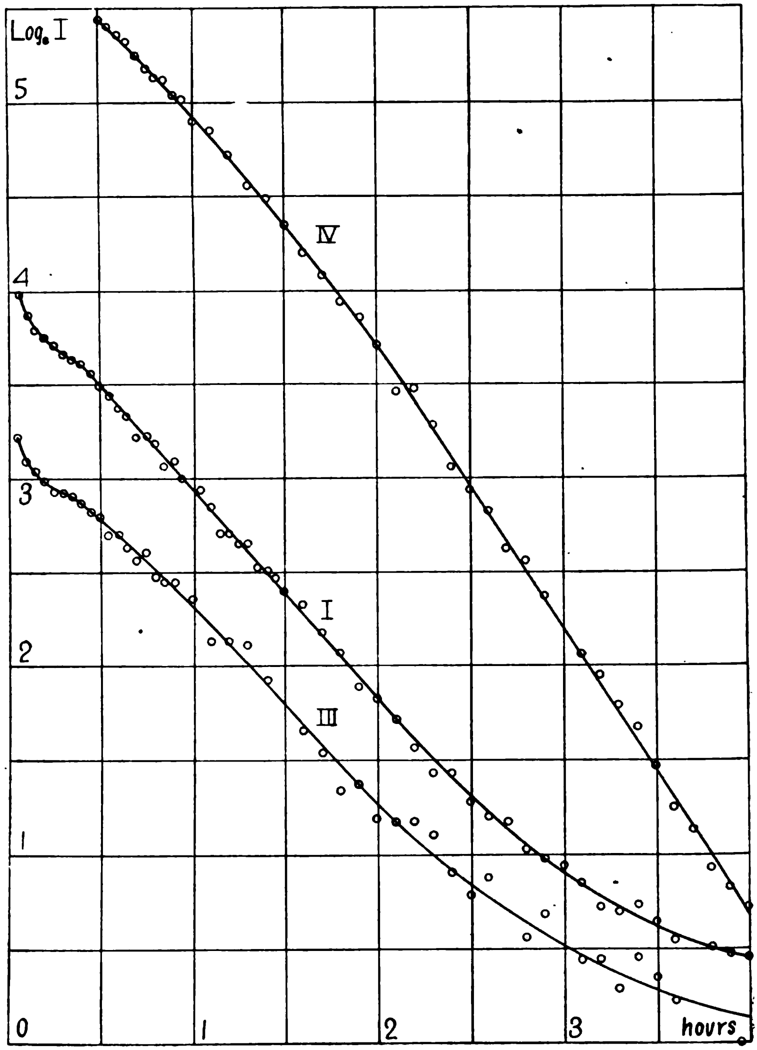
1



taining very weak radium emanation for the same time (3 hours), and charged to the same negative potential by means of the Wimshurst machine. The resemblance is obvious, especially in the initial rapid rate of decay, which is characteristic of the radium-excited activity, and which I have never failed to observe with the open-air wire when two or three observations were taken within the first ten minutes after the exposure ceased. When, however, the observations are carefully compared, it is evident that they do not entirely agree within the limits of experimental error; indeed a mere inspection of the curves in fig. 1 shows that, toward the end, the air wires were falling off at a slightly slower rate than the one exposed to radium emanation. It seemed probable that this

might be due to the presence of a small proportion of some form of activity decaying more slowly than that due to radium, and which would, therefore, show itself in a more and more

2



marked manner as time went on. Accordingly, wires 30 meters long were exposed in the same manner and observations carried on for four hours. The results of two such experiments are plotted in fig. 2, in which, for greater clearness, the nat-

ural logarithms of the ionization currents are plotted as ordinates, the time in hours being the abscissæ.* The curves I and III again represent the air wire, and curve IV a wire exposed to radium emanation, which is given for comparison. The existence of a slowly decaying activity is plainly shown by the curve between two and four hours. Twenty-four hours later, the wire was still appreciably radio-active, but the effect was too small to measure with accuracy; it was about one-fifth as active as at four hours.

In order to determine the rate of decay of this persistent activity, six lengths of wire were suspended in a wide zigzag between the second story windows of two buildings, the total length being 200 meters. They were allowed to sag from the horizontal by different amounts, so that their electrostatic fields should include as much of the surrounding air as possible. The small diameter of the wire made it possible to put this length into the testing vessel without difficulty. Nine hours after introducing it, the current through the cylinder was about six times that due to the "spontaneous ionization," of the air; and this, although small, was measurable with some degree of accuracy. Five observations were made at this time, and five more after an interval of 12 hours; combining them one by one, the following values of the coefficient of decay, λ, were obtained:

$$\begin{array}{r} 0{\cdot}069 \\ 0{\cdot}069 \\ 0{\cdot}066 \\ 0{\cdot}061 \\ 0{\cdot}073 \\ 0{\cdot}065 \\ \hline \lambda = 0{\cdot}067 \end{array}$$

The half-value time corresponding to this coefficient is $10\frac{1}{3}$ hours; and this is so near to the rate of decay of the excited activity due to thorium as to leave little doubt that the slowly decaying activity on the air wire is due to thorium. It is possible to increase the proportion of this to the more transient activity by prolonged exposure of the wire; for the radium-induced activity, an exposure of three hours is sufficient to practically reach the final equilibrium value, while the induced activity due to thorium will continue to increase for several days. By a twelve-hours exposure of a long wire, on a fine,

* On this diagram, radio-active substances which decay according to the same law will give parallel curves; if the law is exponential, the curve will be a straight line and the slope of the line will be equal to λ in the formula, $I = I_0 e^{-\lambda t}$. The zero of ordinates is a matter of indifference so that we may plot log I or (log I $\pm$ const.) as may be most convenient.

clear day, I have succeeded in collecting considerable quantities of this slowly decaying radio-activity. Eleven hours after the wire had been put into the testing cylinder, the current through the gas was 35 times that due to the spontaneous ionization and its gradual decay could be followed for several days. Observations extending over various intervals, from 6 hours to 27, showed that the decay was exponential and the average value of λ, from five determinations, was 0·0616, which indicates a decrease to half in 11·2 hours.

The observations upon the atmospheric activity can be accounted for fairly well, but not quite satisfactorily, by the assumption that it is entirely due to the excited activities of radium and thorium. In the following tables, the second column gives the calculated values of the ionization upon this assumption, the proportion of the two forms of activity being so chosen that the calculated and observed values shall agree at 1 hour and at 4 hours; for the present purpose, the decay of the thorium activity is assumed to be exponential (it is not actually so in the earlier stages) while the decay of the radium activity is found from Curve IV, fig. 2.* The third column gives the observed values for corresponding times, and the last column the differences between the calculated and observed values. The first table represents the experiments plotted in Curve I, fig. 2, the second, those plotted in Curve III.

Curve I.

Assumed,

at 1 hour { Ra. activity = 17·0; Th. activity = 1·6 }

at 4 hours { Ra. activity = 0·244; Th. activity = 1·324 }

t (hours)	Calc.	Obs.	Diff.
1·0	18·6	18·6	0·00
1·5	11·1	10·8	+0·30
2·0	6·48	6·20	+0·28
2·5	3·81	3·69	+0·12
3·0	2·51	2·45	+0·06
3·5	1·89	1·84	+0·05
4·0	1·57	1·57	0·00

Curve III.

Assumed,

at 1 hour { Ra. activity = 8·77; Th. activity = 1·23 }

at 4 hours { Ra. activity = 0·12; Th. activity = 1·02 }

t (hours)	Calc.	Obs.	Diff.
1·0	10·00	10·00	0·00
1·5	6·11	5·95	+0·16
2·0	3·73	3·53	+0·20
2·5	2·33	2·30	+0·03
3·0	1·67	1·67	0·00
3·5	1·32	1·32	0·00
4·0	1·14	1·14	0·00

* Up to 2·5 hours, this Curve IV, and other similar experiments which I have made, give a slightly different result from the empirical formula given by Curie and Danne (C. R., cxxxvi, p. 365, 1903) which is

$$I = I_0 \left[ae^{-\frac{t}{\theta_1}} - (a-1)e^{-\frac{t}{\theta_2}} \right]$$

where $a = 4·20$, $\theta_1 = 2420$ seconds, $\theta_2 = 1860$ seconds. This formula does not take into account the initial rapidly decaying activity due to radium. In the final, exponential part, my results are in close accord with those of Curie and Danne. The half-value time which they obtain is 27·9 minutes, while the value resulting from several experiments of my own is 27·7 minutes.

Although the differences are not large, they are apparently systematic and indicate that, between 1 and 2 hours, the air activity decays a little more rapidly than a combination of excited activities due to radium and thorium, while between 2 and 4 hours it decays more slowly. This cannot be due to the error committed in assuming the thorium activity to be decaying at its final rate; Rutherford has shown that, after a short exposure, thorium-excited activity at first increases so that a correction for this would be in the wrong direction. Another possible explanation of the discrepancy is that it may be due to an error in the determination of the curve for radium; a repetition of the determination, however, does not show any increase in the rate between 1 and 2 hours. If, therefore, we do not regard these differences as due to accidental errors (which seems unlikely in view of their apparent systematic character), they would seem to indicate the presence of a small proportion of some form of excited radio-activity decaying at a more rapid rate than that which the radium activity shows between 1 and 2 hours.* The present experiments are not sufficiently accurate to do more than indicate this as, to some extent, probable; but I am not without hope that it may be possible to go further in this direction by means of careful experiments especially directed to this end. The only other known induced activity, besides those due to radium and thorium, is that due to actinium. According to a recent determination by Debierne,† its decay is exponential and reaches half-value in 40 minutes. Its rate is, therefore, too slow to serve as an explanation of the discrepancy; but if a substance of more rapidly decaying activity is present, a small amount of actinium-excited activity is not impossible since there might be partial compensation between the two.

It is rather remarkable that, although the activity of the air wire is certainly due to a number of different forms of activity, decaying at different rates, the resultant effect between 0·5 and 2 hours is so nearly exponential, as indicated by the straightness of the lines in fig. 2. It is a further coincidence that, in this portion of the curve, the rate is so near the value found by Debierne for the excited activity due to actinium. The half-value time during this interval is, for Curve I, 38 minutes, for Curve III, 41 minutes. If the observations were not extended further, it would be a natural conclusion that the phenomenon was due to actinium emanation in the air. But the known presence of the thorium activity negatives the supposition that any considerable part of the effect can be due to

* Not necessarily more rapid than the final (half-value in 28 minutes) rate of the radium activity.

† Debierne, C. R., Feb. 5, 1904, p. 411.

actinium. The following tables will make this clear; they are like the two previously given except that, in the calculated column, it has been assumed that actinium and thorium activities are present instead of radium and thorium.

CURVE I.

Assumed,

at 1 hour { Actin. activity = 17·6; Th. activity = 0·96 }

at 4 hours { Actin. activity = 0·78; Th. activity = 0·79 }

t hours.	Calc.	Obs.	Diff.
1·0	18·6	18·6	0·00
1·5	11·4	10·8	+0·60
2·0	7·11	6·20	+0·91
2·5	4·56	3·69	+0·87
3·0	3·04	2·45	+0·59
3·5	2·12	1·84	+0·28
4·0	1·57	1·57	0·00

CURVE III.

Assumed,

at 1 hour { Actin. activity = 9·11; Th. activity = 0·89 }

at 4 hours { Actin. activity = 0·40; Th. activity = 0·74 }

t hours.	Calc.	Obs.	Diff.
1·0	10·00	10·00	0·00
1·5	6·27	5·95	+0·32
2·0	4·05	3·53	+0·52
2·5	2·72	2·30	+0·42
3·0	1·92	1·67	+0·25
3·5	1·43	1·32	+0·11
4·0	1·14	1·14	0·00

The differences are much larger than on the assumption of radium and thorium, and are quite beyond any possible experimental errors; and, to get even such an agreement, it is necessary to assume a smaller amount of thorium activity than the observations at later times than four hours will permit. Upon *a priori* grounds also, it is improbable that much of the effect can be due to actinium; the radium emanation is known to be present in the ground and decays so slowly (half-value in four days) that there is ample time for it to diffuse widely through the atmosphere; the actinium emanation, on the other hand, decays with great rapidity (half-value in four seconds),* and unless it were present in the ground in relatively enormous quantities, and not far from the surface, its effects in the open air could not predominate over those of the radium emanation. There is no reason to suppose that it does; any substitution of actinium for radium in the calculated values will cause them to depart more widely from the observed values. But, as previously remarked, if it should turn out that a small amount of a more rapidly decaying activity is present (as there is some reason to suspect), it is not impossible that some actinium activity may also be found. Mr. H. M. Dadourian, to whom I am indebted for assistance in many of the present experiments, is now engaged in an attempt to ascertain more definitely whether such an activity is present or not.

It will be observed that the general slope of Curve III is less rapid than that of Curve I, and that a considerably greater proportion of the thorium activity appears to be present. This, I think, may be accounted for from the known proper-

* Debierne, loc. cit.

ties of the radium and thorium emanations. The experiments plotted in I were made when the ground was hard frozen, and had been so (with occasional superficial thaws) for several months; III is the result of an exposure made a month later when the frost had entirely disappeared from the ground. The decay of the thorium emanation (half-value in one minute) is so rapid, compared with that of the radium emanation, that any delay in its liberation from the ground would considerably diminish the relative amount in the air. According to the accepted theory of radio-activity, due to J. J. Thomson and Rutherford, the disintegration of the gaseous emanation produces a solid material, responsible for the excited radio-activity, which, following Rutherford, we may call emanation X. The particles of emanation X produced by the gas (of either kind) before it leaves the ground would never reach the upper air, since they would not diffuse like the molecules of a gas but would be deposited in the soil; on the other hand, those produced after the escape of the gas would settle very slowly, on account of their small size, and might be carried considerable distances by currents of air. The view that the smaller proportion of thorium activity is due to the frozen condition of the ground, is supported by two other experiments (incomplete and therefore not given in detail), one made while the ground was frozen and the other when it was not; in the latter case the decay was noticeably slower, indicating a larger proportion of the thorium activity. The smaller total activity observed in III might be thought to negative the above explanation; I think, however, that it was due to another cause. There was a very perceptible haze in the air on the day when this experiment was made and little wind; the day of the other experiment was exceptionally clear and a good breeze was blowing. The wind would bring more of the particles of the emanation X within the electric field of the wire, and the fact that they were not loaded with drops of water (or with very small ones) would cause them to move with a greater velocity along the lines of force and hence a greater number might be captured by the wire, even if the number in a cubic centimeter of the air were actually less. The only exposure of a wire which I have made on a clear, windy day since the ground thawed, was one of twelve hours, so that the result is not comparable directly with the three-hour exposure; moreover, the total activity was not observed, but only the thorium effect remaining after ten hours. Reducing this to its value four hours after exposure ceased, taking account of the difference in the lengths of the wires, and assuming that the relation between the thorium activity and the time of exposure is

$$I_t = I\left(1 - e^{-\lambda t}\right),$$

the value obtained indicates that about 75 per cent more thorium activity would have been deposited on wires of equal lengths, in the same time, on the clear day when the ground was not frozen than upon the clear day when it was.

A similar explanation may be given of the fact that the radio-activity of rain and snow, discovered by C. T. R. Wilson, decays at a different rate from that of the negatively charged wire. Wilson finds that the former falls to half-value in about 30 minutes;* and this is very near to the final rate of the radium-excited activity. If we assume that some of the drops in the rain clouds are condensed upon the positively charged particles of radium emanation X present in the air, the time occupied by the drops in falling, and in the collection and evaporation of the water, would prevent the earlier, non-exponential decay of this activity from being observed; all that would remain would be the final, regularly decaying product. The absence of a noticeable amount of thorium activity may be explained by the rapid decay of the thorium emanation; although the particles of thorium emanation X, present near the ground may sometimes be carried to considerable heights by the wind, the proportion of radium activity must steadily increase as we go upward, since, in the case of the radium activity, we have not only the particles blown up from near the ground but also those produced by the radium emanation *in situ*; the slow decay of this emanation allowing it to diffuse to much greater heights than the thorium emanation. It is to be expected that a negatively charged wire suspended several hundred feet above the ground would show a smaller proportion of thorium than one exposed near the earth's surface.

I have also looked for evidence of the presence of the thorium and actinium emanations in the soil but, up to the present, without definite results. It is, of course, useless for this purpose to draw air from the ground and introduce it into an electroscope or condenser, as in testing for the radium emanation, on account of the rapid decay of the thorium and actinium emanations. A galvanized sheet-iron pipe 15^{cm} in diameter and 2 meters long, with open bottom, was sunk in the ground and a negatively charged wire suspended in it. The top was closed and a gentle current of air was drawn through the cylinder (entering at the open bottom from the ground) by means of a filter pump. The wire did not acquire sufficient radio-activity to enable one to follow its decay for more than two hours, and, even during this time, the ionization produced in the cylinder

* Proc. Camb. Phil. Soc., xii, p. 17 (1902).

was too small for accurate observations to be made. The rate appeared to be somewhat slower than that of the excited activity due to radium but no great confidence can be placed in the result. It is likely that a larger cavity in the ground would give more definite results but I have not yet been able to try this.

Conclusions.

1. The radio-activity acquired by a negatively charged wire exposed in the open air (at least as observed in New Haven) is mainly, if not wholly, due to the excited activities of radium and thorium. With a three-hour exposure, 3 to 5 per cent of the total initial effect is due to the thorium activity, the proportion depending apparently upon the greater or less ease with which the emanations escape from the soil. With a twelve-hour exposure the thorium activity is sometimes 15 per cent of the whole, and with a long wire, its decay may be followed for several days. There is some evidence that a small quantity of a more rapidly decaying activity is present in addition, but these experiments do not definitely establish this.

2. The radio-activity of rain and snow is probably due to radium-excited activity, the absence of the thorium effect being accounted for by the fact that the rapid decay of the thorium emanation prevents its reaching, in appreciable quantities, the height at which the rain-drops are formed.

Sheffield Scientific School of Yale University, April, 1904.

ART. II. — *Studies in the Cyperaceæ;* by THEO. HOLM. XXII. The Cyperaceæ of the Chilliwack Valley, British Columbia (between lat. 49° and lat. 49° 10′; and long. 121° 25′ and long. 122°). (With figures in the text drawn from nature by the author.)

THROUGH the courtesy of Mr. James M. Macoun, the writer has had an opportunity of examining a collection of *Cyperaceæ* which was made by him in the Chilliwack Valley during the summer of 1901, and upon which we take pleasure in presenting the following report. With the exception of *Scirpus Macounii* most of the others are old and well known species, but nevertheless of some interest from a geographical point of view, besides that, several of these represent types that have not hitherto been clearly accounted for, viz: *Carex scirpoidea*, *C. vulgaris* var. *lipocarpa*, *C. spectabilis*, etc.

I. SYNOPSIS OF THE SPECIES.

Carex.

VIGNEA.

Brachystachyæ nob.

Carex canescens L. Boggy spots, the lake (No. 26,651).

C. vitilis Fr. Swamps, the lake (No. 26,652) and among moss on rocks, 3,500 ft. alt. (No. 26,659).

C. arcta Boott. By marshes, Sumas Lake (No. 26,653).

Neurochlænæ nob.

C. nardina Fr. Crevices of rocks, 6,500 ft. alt., Tami Hy Mountain (No. 33,689).

Argyranthæ nob.

C. Deweyana Schw. Woods, the river (No. 26,644).

C. Deweyana Schw. var. *Bolanderi* Boott. Grassy slopes, 2,000 ft. alt. (No. 26,655); banks of streams, the river (No. 26,654); stumps by streams, the lake (No. 26,643).

Astrostachyæ nob.

C. interior Bail. Boggy marsh, east of the lake (No. 26,658).

C. læviculmis Meinshaus. Swampy places, the river (No. 26,657) and boggy spots, the lake (No. 26,656).

Stenorhynchæ nob.

C. stipata Muehl. Along ditches, near town (No. 33,736).

Phænocarpæ nob.

C. teretiuscula Good. var. *ramosa* Boott. Marshes east of the lake (No. 33,743).

Athrostachyæ nob.

C. Crawfordii Fern. By ditches (No. 26,649).

C. festiva Dew. By rivulets, 5,500 ft. alt., Tami Hy Mt. (No. 26,646) and along the river at 4,000 ft. alt. (No. 26,645). (Fig. 1.)

C. festiva Dew. var. Gravel bars, the river (Nos. 26,647–48). (Fig. 5.)

Pterocarpæ nob.

C. Bebbii Olney. In mud by the river (No. 26,650).

CARICES GENUINÆ.

Melananthæ Drej.

C. Mertensii Prescott. By springs, the river (No. 33,670) and by rivulets, the lake (Nos. 33,671–72).

C. spectabilis Dew. Near melting snow, 5,000 ft. alt., Tami Hy Mt. (No. 33,659). (Fig. A.)

Microrhynchæ Drej.

C. vulgaris Fr. var. *lipocarpa* nob. By a rivulet, 4,000 ft. alt., the lake (No. 33,631) and by a pond, Tami Hy Mt. (No. 33,630).

C. dives nob. Marshes, the lake (No. 33,753).

Lejochlænæ nob.

C. polytrichoides Muehl. Marshes, the lake (No. 33,660).

C. Hendersoni Bail. In thickets of *Alnus* and *Acer glabrum*, alluvial soil along the river (No. 33,657).

Athrochlænæ nob.

C. nigricans Mey. Near melting snow, 5,000 ft. alt., Tami Hy Mt. (No. 33,705).

Stenocarpæ nob.

C. ablata Bail. Damp Banks, 4,000 ft. alt., the lake (No. 33,715).

Sphæridiophoræ Drej.

C. scirpoidea Michx. var. *stenochlæna* nob. By a rivulet, 4,000 ft. alt., the lake (No. 33,728). (Fig. 7.)

C. Rossii Boott. Rocky woods, the lake (No. 33,634) and on a snow-slide (No. 33,747).

Physocarpæ Drej.

C. utriculata Boott. Marshes east of the lake (No. 33,642).

Scirpeæ

Eleocharis ovata R. Br. (No. 34,772).
E. palustris R. Br. (No. 34,773).
Scirpus cæspitosus L. Alt. 3,500 ft. (No. 34,770).
S. Macounii nob. (No. 34,771). (Fig. 9.)
Eriophorum gracile Koch. (No. 34,769).
E. angustifolium Roth. Alt. 5,000 ft. (No. 34,768).

II. Notes on New or Little Known Species.

Carex vitilis Fries.

Several authors have generally confounded this well defined species with *C. brunnescens* (Pers.) Poir., known also as *C. Persoonii Sieber*, and *C. Gebhardi* Hoppe, furnishing a diagnosis which may be well suitable to both, but far from correct as to either. Both have been very clearly defined by Fries himself,* by Koch,† Blytt‡ and various others, and the distinctive characters may be drawn up as follows: The inflorescence of *C. vitilis* is composed of about five, remote, subglobose spikes with yellowish, spreading perigynia of which the beak is quite distinct and almost entire. In *C. Persoonii*, on the other hand, the spikes are oblong, brownish, and the perigynia are not spreading, but erect with a beak slit in its entire length on the outer, convex face. Both species are closely related to the frequent *C. canescens* L. but from which they are readily distinguished, however, by their color, as indicated, their slender culms and narrow leaves, and especially by the structure and position of the perigynium.

If this distinction be sufficient for considering *C. vitilis* and *C. Persoonii* valid species, a view which the writer feels most inclined to uphold, the latter, *C. Persoonii*, evidently does not occur on this continent, judging from the fact that we have never observed it in any of the large collections so far examined.

Carex festiva Dew.

Very few *Vigneæ* exhibit such pronounced ability to vary as is possessed by this species, and the plasticity becomes especially noticeable when we compare individuals from various stations from East to West: from Scandinavia to the Pacific slope, rather than from North to South or at different elevations in the mountains. For strange as it seems, several of the most characteristic deviations from the type often occur at the same altitude, from the subalpine to the high alpine regions, besides

* Fries, Elias: Novit. Floræ Suecicæ mantissæ, iii, p. 137.
Same: Summa veget. Scand., 1846, p. 223.
Same: Botan. Notiser, Lund., 1844, p. 23.
† Koch: Synopsis Floræ Germ. et Helvet., ii, 1857, p. 655.
‡ Blytt, M. N.: Norges Flora., i, 1861, p. 199.

that none of these seem restricted to certain northern or southern latitudes. On the other hand, the variation of *C. festiva* appears to be well marked in proportion to longitude, and it so happens that while the type seems to be equally dispersed from Alaska to Scandinavia, certain varieties are restricted to within the boundaries of the Pacific slope eastward to the Rocky Mountains, in other words, the species affords an excellent example of longitudinal variation, which we believe is a feature common to plants of southern origin in contrast to northern types.

Now in regard to the plant from Chilliwack Valley, and we refer especially to Nos. 26,645 and 46, this seems to represent the species as it is generally recognized, although the perigynium (fig. 1) is faintly several-nerved, and it must be borne in mind that Dewey makes no mention of such nervation in his diagnosis of the species:* "Spicis distigmaticis androgynis, superne pistilliferis subsenis ovatis in capitulum dense aggregatis; fructibus ovatis oblongis rostratis in apice serrulatis bifidis convexo-planis, squama ovata acutiuscula longioribus."

The specimens upon which the species was established came from "Bear Lake and the Rocky Mountains." However, all subsequent authors describe the perigynium as nerved on both faces, faintly or even prominently so, and Boott,† " who had authentic material at his disposal, did not hesitate to refer similar specimens with the perigynium "nervose" to this species of Dewey. And, so far, all individuals that have been examined and described exhibit such nervation to a more or less extent, a character that seems, besides, to be common to all the varieties known. It may be that the Chilliwack plant is nearer the type than any of the others on account of the perigynium being merely faintly few-nerved, but otherwise it is hardly different from the one figured as No. 2 on the same plate, taken from a specimen collected at Kananaskis in the Rocky Mountains of British Columbia. We might here call attention to the fact that the majority of specimens, generally recognized as typical, from this continent as well as from Greenland and Scandinavia exhibit the same nervation and outline of perigynium as the plant from Kananaskis (fig. 2). The habit of these specimens is exactly the same, furthermore the shape and color of the inflorescence is also similar. If we, on the other hand, examine some of the varieties, for instance "*decumbens*" (fig. 4), we observe a perigynium of much larger proportions and a habit, which is very distinct, and which, to some extent, may call to mind that of *Carex incurva Lightf.* In the var. *Haydeniana* (fig. 3) the perigynium shows the same nervation,

* This Journal, vol. xxix, 1836, p. 246.
† Illustr. of the genus *Carex*, vol. 1, p. 26.

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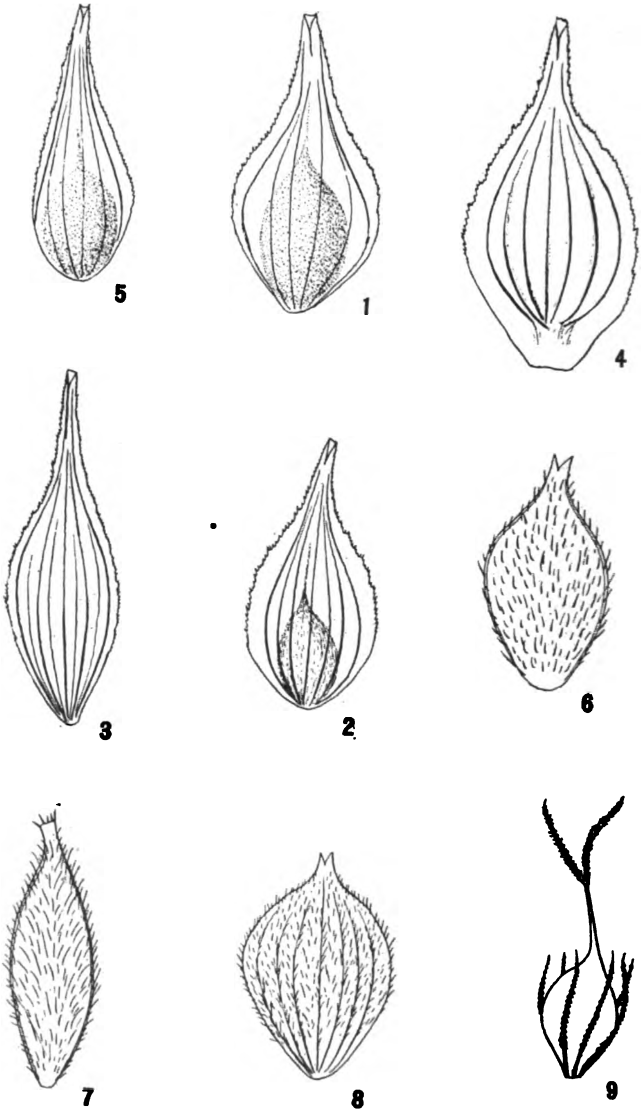

Theo. Holm delin.

but the outline is very different, the body being very narrow and the beak relatively longer than in the typical plant, besides that the color of the spikes is very dark, almost black. Never-

theless, none of these varieties seem sufficiently characteristic for being considered as specifically distinct, inasmuch as many intergradating forms have been observed between these and the one which we consider typical.

There is, still, another *Carex* from the Chilliwack Valley, which we are most inclined to refer to this same species, although its very slender culms and leaves, besides the conspicuously spreading perigynia, make it somewhat anomalous as *C. festiva*. Specimens of this plant (No. 26,647–48) were labeled *C. illota* Bailey by Mr. Macoun, and from their habit they are not unlike this species, which, however, is identical with Kunth's *C. Bonplandii* var. *angustifolia*. An examination of the perigynium (fig. 5) proved, however, that this does not show the structure of that of *C. Bonplandii*, but rather that of *C. festiva*, hence we prefer to enumerate it, at least "ad interim," as a variety of the latter.

Carex spectabilis Dew. (fig. A, p. 18.)

The original diagnosis* reads as follows: "Culm 8 to 12 inches high, erect, smooth, striate; leaves sheating, flat and smooth, upper ones about equalling the culms; bracts long and leafy; staminate spike single, erect, cylindric and oblong, with oblong obtusish scales; stigmas 3; pistillate spikes 2 to 3, ovate, cylindric, erect, remotish, pedunculate, and the lowest long-pedunculate, sheaths short; fruit ovate, obtuse nerved, scarcely rostrate, orifice two-lobed; pistillate scale oblong, lanceolate, short mucronate, all reddish brown, and a little longer than the fruit. Found in the Arctic regions."

Carex spectabilis in several respects is suggestive of *C. macrochæta* Mey., but differs constantly from this by its merely mucronate squamæ, the cylindrical and dense-flowered spikes, the two-lobed or simply emarginate orifice of the perigynium (figs. a, b and c), of which only three nerves are visible on the outer face. In *C. macrochæta* the scales are aristate, the mid-vein being very much extended beyond the apex of the scale, the spikes are relatively shorter and lax-flowered; furthermore, the perigynium is quite prominently several-nerved and the orifice entire (fig. d) and constantly so, judging from the numerous specimens which we have examined. But common to both are the aphyllopodic culms and distinctly pedunculate pistillate spikes, which, however, are often drooping in *C. macrochæta*, but merely spreading or erect in *C. spectabilis*. As to the color of the foliage, it appears as if the leaves and perigynia are deeper green in the latter.

* This Journal, vol. xxix, 1836, p. 248.

The systematic position of *C. macrochæta* seems most naturally to be among the *Aeorastachyæ*, but in regard to the other species, certain analogies exist between this and *C. atrata*, *C. Mertensii* and their allies, thus we have placed *C. spectabi-*

lis as the last member of the *Melananthæ*, showing transition to the former "grex" through *C. macrochæta*. The geographical distribution of *C. spectabilis* extends from the Chilliwack Valley south to California, but the species is evidently quite rare.

Carex vulgaris Fr. var. *lipocarpa* nob.

Most of the material of *C. vulgaris* secured from the Northwest belongs to this variety, and it is this plant which by recent American Caricographers has been identified as Boott's *C. decidua.* Mr. C. B. Clarke has called our attention to this mistake, and we owe to him the important information, that even if Boott at one time considered both of these identical, he, later on, corrected the determination in regard to the West American plant, and reserved the specific name *decidua* to the South American exclusively.

The diagnosis of *C. decidua* was published in Transacts. Linn. Soc. (vol. xx, 1845, p. 119), and the following points may be quoted as sufficient for distinguishing the species from varieties of *C. vulgaris:* "spicis 4–7 erectis; suprema mascula vel androgyna basi vel apice et basi mascula—perigyniis denticulato—serratis." It is no doubt a near ally of *C. vulgaris*, and perhaps more especially so of the variety *lipocarpa*, but even if the perigynia and the scales are deciduous in both, the characters enumerated above are not to be observed in this particular form of *C. vulgaris.*

Carex dives nob.

No. 33,753 of this collection was identified by Mr. Macoun as *C. variabilis* Bail. var. *elatior* Bail., but it differs in several essential points from this variety and can not be referred to *C. variabilis.* Habitually it is more like *C. Sitchensis* Presc., but the spikes are more numerous, more dense-flowered, the squamæ lack the characteristic spot at the apex, the perigynium is broader, prominently granular and often spinulose along the upper margins, hence we have identified the species as our *C. dives*, established upon a plant from Oregon, collected several years ago by Professor Henderson. The species is closely allied to *C. Sitchensis*, and may be placed near this and *C. acuta* of the *Microrhynchæ.*

Carex Hendersonii Bail.

This represents the Western and especially the Northwestern type of the higher developed *Lejochlænæ* of this continent, the others showing a decided Eastern distribution, for instance *C. laxiflora*, *C. plantaginea*, *C. digitalis*, etc. But among the lower forms, among those which we have enume-

rated as "hebetatæ," are some, which are also characteristic of the Western States, e. g., *C. Geyeri* and *C. multicaulis*, while *C. polytrichoides* is rare in that part of the continent, but abundant in the East, on the Atlantic slope.

Carex scirpoidea Michx.

The original diagnosis reads: "C. planifolia, dioica," spica unica, imbricato-cylindrica: capsulis dense pubescentibus, Hab. ad sinum Hudsonis."*

The first specimens known were thus monostachyous, but since then the species has been observed as being, and not very uncommonly so, distachyous: with a small, lateral spike, staminate in the staminate plant, pistillate in the pistillate, developed in the axil of a bract, which is always noticeable in a short distance below the terminal spike, as already mentioned by Drejer, who observed this peculiarity in Greenland specimens. The geographical distribution has been widely extended from Hudson Bay throughout the continent towards the Atlantic and Pacific slope, as far south as Colorado and California, besides that the species has been recorded from Greenland and even from the mountains of northern Norway, where it, however, seems to be very rare. It is very natural that a species, so widely dispersed, exhibits some variation, and as indicated in the enumeration of the species the Chilliwack plant deviates to some extent from the typical, the one from Hudson Bay, which is, also, the most commonly met with. We have, furthermore, noticed some peculiarities in the Californian plant, which seem to warrant the proposition of some varieties. The variation, however, seems confined to the structure of the utricle rather than to the relative size of the plant, its robustness, the outline of the spike, etc., characters that seem too variable to be depended upon in any species of the genus. The Chilliwack plant may be described as follows:

var. *stenochlæna* nob.

A very tall and slender plant with the pistillate spike clavate, loose flowered, especially at the base, the perigynium (fig. 7) longer and much narrower than in the type, spreading, very densely pubescent, with the orifice of the beak entire, ciliate; stigmata 3. Also collected in Alaska: Juneau and by Yes Bay.

var. *gigas* nob. (fig. 8).

Spikes mostly 2, very robust and dense-flowered; the number of bracts sometimes 3 (2 empty); perigynium broader than in the type, loosely pubescent and distinctly many-nerved, orifice of the beak as in the type, bidentate; stigmata 2 or 3,

* Michaux: Flora boreali-Americana, ii, 171.

the style not exserted. Only known from Siskyiou County, California: Mt. Eddy.*

Scirpus Macounii sp. n. (fig. 9).

Perennial with ascending shoots, the leaf-sheaths not fibrillose; basal leaves much shorter than the culm, flat, about 1^{cm} wide, the midrib distinct, very scabrous below, glabrous above, light green; cauline leaves with long sheaths; culm erect, triangular scabrous, leafy to about the middle, one meter in height, phyllopodic; inflorescence umbellate, decompound, the primary rays scabrous, from 1 to 7^{cm} in length subtended by long, foliaceous involucral bracts and small, tubular prophylla with or without a short setiform blade; secondary rays many but much shorter, only 1 to 3^{cm} in length, subtended by scale-like leaves and minute prophylla; spikes 3 to 6 together, sessile, cylindric, about half a centimeter in length; scales greenish brown, lanceolate, acuminate, the midrib stout and extended into a short mucro; setæ 6, straight, a little longer than the caryopsis, downwardly barbed to near the base; stamens 2, seldom 3; stigmata 2 or 3; caryopsis light brown, roundish in outline, compressed triangular in cross-section.

Evidently a near ally of *S. sylvaticus*, but in this the scales are obovate-oblong, slightly emarginate with a short mucro from the extended midrib, the stamens are only 2 in number, the setæ 4 and the stigmata nearly always 2, besides that the spikes are shorter and more oval.

III. The Geographical Distribution.

The *Cyperaceæ* of the Chilliwack Valley represent certain types of wide geographical range, some of which are arctic: *Carex nardina*, *festiva*, *scirpoidea*, *Eriophorum gracile* and *Scirpus cæspitosus*, while *Carex canescens* and *Eriophorum angustifolium* are even circumpolar. Some others are confined to this continent, but extend as far east as the Atlantic slope, for instance *Carex Bebbii*, *interior*, *Crawfordii*, *Deweyana*, *arcta*, *stipata*, *teretiuscula* and *polytrichoides*, while *C. læviculmis*, *Mertensii*, *spectabilis*, *vulgaris* var. *lipocarpa*, *dives*, *Hendersonii*, *nigricans*, *ablata* and *Rossii* are mostly western species, sometimes, however, extending eastward to the Rocky Mountains. *Eleocharis palustris* is cosmopolitan, and *E. ovata* is known from Middle Europe, Caucasus and Dahuria, besides from Australia.

Moreover, some of these species occur as alpine farther south,

* *C. pseudoscirpoidea* Rydberg has been described in the Flora of Montana (p. 78) as a segregate from *C. scirpoidea* Michx., but we find none of the characters sufficient for segregating the Montana plant from the type; moreover, the description is incorrect, for instance the perigynium is said to be "densely hirsute" instead of merely "pubescent," etc., besides that the name "Greek-Latin-Greek" is not admissible.

in Colorado: *Carex nardina* and *festiva*, while *C. Rossii*, *nigricans* and *scirpoidea* (the typical) are merely subalpine.

When we consider the *Cyperaceæ* of the Chilliwack Valley by themselves, they offer a strange commingling of types not only in regard to their distribution elsewhere, but, also, in respect to the types they represent. No doubt the flora of the valley has been influenced, and to a great extent, by the receding ice during the glacial epoch, when a number of plant-species moved north by way of the Rocky Mountains, but there is, also, some evidence of other species having reached this place in a much later period, for instance the eastern species.

It would be interesting to know how the geographical distribution compares with the other orders, and quite especially with those that contain types of the arctic or at least of the northern Flora, such as the *Saxifragaceæ*, *Ranunculaceæ*, *Juncaceæ* and *Gramineæ*. And in regard to the types, as we have seen these represented by the *Cyperaceæ*, it is somewhat strange to see so many *Vigneæ* in proportion to *Carices genuinæ* in a corner of the continent, where the latter usually appear to be predominating in species as well as in individuals; for the latter are really poorly represented, when compared with those of the Alaskan coast and Oregon. This seems the more remarkable when we notice that the *Scirpeæ* of the valley are the same, almost, as those of Alaska and vicinity.

As far as concerns the *Cyperaceæ*, the valley seems to have been a meeting-place of a number of species from remote localities and of remarkably specialized types, so utterly unlike each other. The magnificent collections and carefully drawn observations will, no doubt, enable Mr. Macoun to further illustrate the character, the composition and origin of this interesting vegetation.

EXPLANATION OF FIGURE I.

FIGURE 1.—Perigynium of *Carex festiva* (No. 26,646) Chilliwack Valley; magnified.
FIGURE 2.—Perigynium of *Carex festiva* from Kananaskis, Rocky Mts., B. C.
FIGURE 3.—Perigynium of same var. *Haydeniana* from Mt. Massive, Colorado.
FIGURE 4.—Perigynium of same var. *decumbens* from Pagosa peak, Colorado.
FIGURE 5.—Perigynium of same var. (No. 26,648) from Chilliwack Valley.
FIGURE 6.—Perigynium of *C. scirpoidea* (typical) from Montana.
FIGURE 7.—Perigynium of *C. scirpoidea* var. *stenochlæna* from Chilliwack Valley.
FIGURE 8.—Perigynium of *C. scirpoidea* var. *gigas* from Mt. Eddy, California.
FIGURE 9.—Caryopsis and setæ of *Scirpus Macounii* sp. n.

FIGURE II.

Carex spectabilis from Chilliwack Valley; natural size.

FIGURE *a*.—Perigynium of same, magnified.
FIGURE *b*.—Perigynium of same from Nevada County, California.
FIGURE *c*.—Perigynium of same from Kicking Horse Lake, B. C.
FIGURE *d*.—Perigynium of *C. macrochæta* from Alaska.

ART. III.—*Note on a New Permian Xiphosuran from Kansas;* by CHARLES E. BEECHER.*

THROUGH the courtesy of Mr. J. W. Beede, of Indiana University, the writer has had an opportunity to examine a portion of the cephalothorax of a large Xiphosuran from the Permian of Kansas. It apparently belongs to the genus *Prestwichia* and it is chiefly interesting, aside from its large size, on account of its coming from a higher horizon than any other American species yet known.

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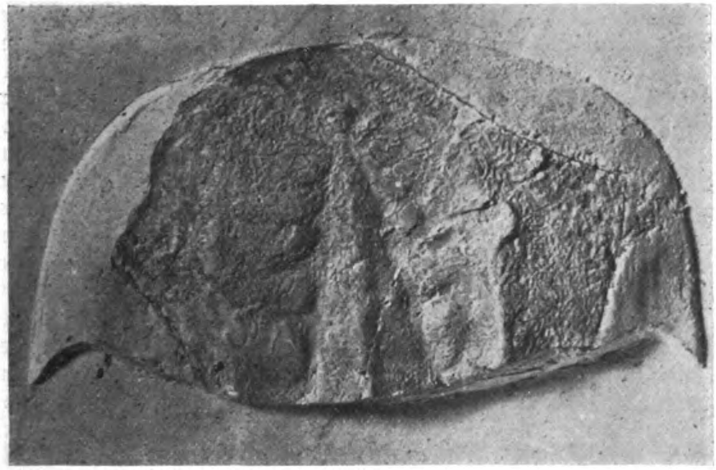

FIGURE 1.—*Prestwichia signata* restored and of natural size. The smooth lateral or genal regions are the parts restored.

In the March number of the American Geologist for 1902, the writer described a species of *Prestwichia* from the Chemung (Devonian) of Pennsylvania, which carried the geological distribution of the genus from the Coal Measures to the Upper Devonian. The present species extends its range in the other direction as far as the lower Permian. The Carboniferous forms of *Prestwichia* in general show very little evidence of the segmental nature of the cephalothorax, and it was of considerable interest to describe in the Chemung species a series of nodes on each side of the glabellar region corresponding, it was believed, to five of the six pairs of appendages on the ventral side. The new Permian form also exhibits a similar series of appendicular lobes on each side of the axis, which agree in

* Among the papers of the late Professor Beecher was found the manuscript of this article as here printed. The manuscript was compared with the cast of the fossil and found to be complete as far as the very imperfect but interesting specimen will permit.—CHARLES SCHUCHERT.

position and form with the earlier species. It is also possible to detect an additional anterior pair, making the full number of six altogether.

Prestwichia signata, sp. nov. (figure 1).

A diagnosis of the species is necessarily quite incomplete, owing to the fact that thus far only a portion of the internal mold of a single cephalothorax has been discovered. It is believed, however, that the characters preserved will readily serve to identify the species, which is geologically quite important.

Cephalothorax large, depressed, convex, flattened on the dorsal side between the eyes, slightly arched in a longitudinal direction. The glabellar region is marked by a subconical elevation, angular along the median line, and terminating in front by a small, round ocellar node, distant from the anterior margin about one-sixth of the estimated length of the cephalothorax. Extending from the posterior margin of the cephalothorax are two low subangular ridges starting at points from the median line equal to the basal diameter of the glabellar cone, passing forward and curving slightly outward to the eyes, thence turning a little toward the axis and merging into the general contour before reaching the anterior end of the cone. The space thus enclosed on each side is occupied by five low rounded nodes, of which the posterior one is somewhat the larger and obliquely pointed behind. Just at the apex of the cone, and behind the ocellar node, is a pair of small transverse nodes, thus making six on each side. The second and third of each series are faintly delimited, while the fourth, fifth, and sixth are very clearly shown. The glabellar axis also shows extremely faint annulations corresponding to the lateral lobes. Opposite the third pair of lobes are the reniform or crescentic eyes, which are large and prominent for the genus. Two minute spots on each side of the small anterior median lobe, and distant from each other about $1 \cdot 5^{mm}$, indicate the ocelli.

The surface of the specimen represents a mold of the inner surface of the test, and is covered with a plexus of very slender anastomosing vascular furrows and ridges, much like those in the modern *Limulus*.

The cephalothorax as preserved has a length of 45^{mm}. The glabellar cone measures 33^{mm} in length and 18^{mm} across at the base. The outer edge of the eyes is about 20^{mm} distant from the median line and measures fully 5^{mm} in anteroposterior diameter.

Genal regions, abdomen, and telson unknown.

Horizon and Locality.—In the Fort Riley limestone of the lower Permian, three miles west of Stockdale, Kansas. The plastotype is in the Yale University Museum.

Laboratory of Paleontology, Yale University Museum,
New Haven, Connecticut, December 1, 1903.

Art. IV.—*Kunzite and its Unique Properties;* by Charles Baskerville and George F. Kunz.

In a recent investigation* made by us on the behavior of a large number of minerals and gems with various forms of radiant energy, including the emanations, as well as on the production of luminescence in some cases by other physical means, the new variety of spodumene, designated kunzite, was found to be peculiarly sensitive, and to exhibit some remarkable properties.

In general, as shown by these investigations, the gem-minerals were little affected by ultra-violet rays: but three species exhibited a high degree of responsiveness to these and to all forms of radio-activity, so far experimented with. These minerals were diamonds of certain kinds; willemite (zinc orthosilicate), which in some cases has been used as a gem-stone, and kunzite. The behavior of the last, as noted in various experiments, is unique and will be briefly described here by itself.

1. *Attrition and heat.*—Kunzite does not become luminous by attrition, or rubbing. Several specimens were held on a revolving buff cloth making 3000 revolutions per minute, so hot as to be almost unbearable to the hand, and still it failed to become luminous. Wollastonite, willemite and pectolite are, however, very tribo-luminescent.

As to luminescence induced by heat alone, it was found that kunzite does possess the property of thermo-luminescence to some extent, with an orange tint and at a low degree of heat.

2. *Electricity.*—The mineral assumes a static charge of electricity, like topaz, when rubbed with a woolen cloth. On exposing kunzite crystals of different sizes to the passage of an oscillating current obtained from large Helmholtz machines, the entire crystal glowed an orange-pink, temporarily losing the lilac color. A well-defined, brilliant line of light appeared through the center, apparently in the path of the current. On discontinuing the current, the crystal gave the appearance of a glowing coal. It was not hot, however, and the phosphorescence lasted for forty-five minutes.

Three large crystals, weighing 200, 300 and 400 grams each, were attached to copper wires so that the current passed in one instance from below up, and from the other upwards across the crystal—first across the prism, then parallel with the prism. In each instance the crystals became distinctively luminous, a pale orange-pink, and between the two wires a bright almost

* Science, N. S., xviii, 769, 1903.

transparent line passed from one wire to the other; in reality, as if the two elongated cones crossed each other, the line of the path being transparent at the sides, whereas the rest of the crystals appeared translucent. After the exposure of two minutes, they were laid upon photographic plates and in five minutes produced a fine auto-print, herewith shown. The crystals continued to glow for forty-five minutes.

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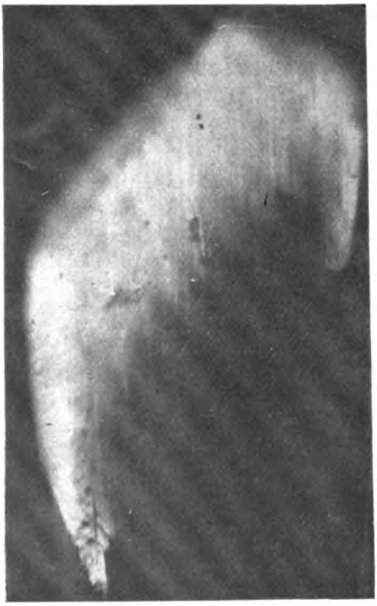

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FIGURE 1.—Self-print made by the exposure of crystal of kunzite to the Roentgen rays for five minutes. Note the frond-like emanations at the ends of the crystal.—Reduced one-half.

FIGURE 2.—Auto-print of crystal of kunzite luminescence induced by an oscillating current obtained from a Helmholtz machine.—Reduced one-half.

When a cut gem is suspended between the two poles, it becomes an intense orange-pink color, glowing with wonderful brilliancy. The discharge seemed as if it would tear the gem asunder, although actually it was unaffected.

3. *Ultra-violet rays.*—These invisible rays, produced by sparking a high voltage current between iron terminals, caused kunzite, white, pink or lilac, to phosphoresce for some minutes. The white responded most readily.

4. *Roentgen, or X-rays.*—All forms of kunzite become

strongly phosphorescent under these rays. An exposure of half a minute caused three cut gems to glow first a golden-pink, and then white for ten minutes. The glow was visible through two thicknesses of white paper, which was held over it. A large crystal excited for five minutes afterward affected a sensitive photographic plate.* Another crystal, exposed for ten minutes, was laid for five minutes on a sensitive plate.† The resulting auto-photograph was clear and distinct, but presented a very curious aspect not seen by the eye—as of a misty or feathery outflow from the side and termination of the crystal, suggesting an actual picture of the invisible lines of force. The other varieties of spodumene, mineral material and cut gems, failed to show this property. We are not yet in a position to offer a satisfactory explanation of the above.

Whereas kunzite is so responsive and fluorescent and so beautiful upon exposure to the X-rays, it is, however, like all silicates, opaque to the ray itself. Four crystals weighing 100, 200 and 400 grams each, were exposed to the Roentgen ray for two minutes. They became first a beautiful rose-orange, then assumed a white phosphorescence, and at the end of forty-five minutes there was still a faint residual glow. Two minutes exposure to the X-ray caused them to print a perfect auto-type (herewith shown, fig. 2). The glow in all instances showed first a rose-orange color, then a pale pink, finally resolving into a white fluorescence; the auto-print shows the feathery outlines of light or energy thrown out by the crystal.

5. *Conduct with radium preparations.*—Exposed for a few minutes to radium bromide with a radio-active strength of 300,000 (uranium being taken as unity), the mineral becomes wonderfully phosphorescent, the glow continuing persistently after the removal of the source of excitation. The bromide was confined in glass. Six hundred grams of kunzite crystals were thus excited with 127 milligrams of the radium bromide in five minutes. The effect is not produced instantaneously but is cumulative, and after a few moments exposure the mineral begins to glow, and its phosphorescence is pronounced after the removal of the radio-active body. The luminosity continued in the dark for some little time after the radium was taken away. No other varieties of spodumene examined, including hiddenite, gave like results. In this respect, as with the Roentgen rays, the kunzite variety stands by itself.

When pulverized kunzite is mixed with radium-barium chloride of 240 activity or carbonate of lower activity, the mixed powder becomes luminous and apparently remains so permanently; i. e., in several months no loss has been observed.

* Science, N. S., xviii, 303, 1903.
† This was made by Dr. H. G. Piffard of New York City.

The same is the case if pulverized wollastonite or pectolite be used instead of the kunzite. When either of these mixtures is put in a Bologna flask and laid on a heated metal plate (less than red-hot), the powder becomes incandescent and remains so for a long time after removal.

These three minerals phosphoresce by heat alone, as was mentioned above in regard to kunzite. Perhaps this luminosity of the mixed powders at the ordinary temperature may be accounted for in part by the evolution of heat* on the part of the radium compounds, but there are experimental reasons which cause us to reject such explanation for the total effect.

The *emanation* of radium, the α-rays, according to Rutherford† are condensed at a temperature of $-130°$ to $-140°$ C. The emanations were driven from radium chloride by heat and condensed with liquid air on a number of kunzite crystals, according to a method which will be described by one of us (B) and Lockhart in another paper, and *no phosphorescence observed.* Consequently *kunzite responds only to the γ-rays,* which are believed to be virtually Roentgen rays.

6. *Actinium.*—A sample of the still more rare and novel substance discoverd by Professor Debierne‡ and received from him through the courtesy of Professor Curie, was also tried as to its action upon kunzite and some other minerals. The actinium oxide, with an activity of 10,000 according to the uranium standard, gave off profuse emanations and affected diamonds, kunzite and willemite in a manner similar to the radium salts, with quite as much after-continuance. However, we have not tried the condensation of these emanations upon the minerals by refrigeration.

The peculiar properties of the kunzite variety of spodumene, which have been enumerated, have not been observed in any other of the gem or gem-minerals that we have examined. It is barely possible that the small amount of manganese may have much to do with it, but from our present knowledge basing a chemical explanation thereon is idle.

* P. Curie and Laborde, Comptes Rend., cxxxvi, 673.
† Phil. Mag., v, 561. ‡ Compt. Rend., cxxix, 593.

ART. V.—*Analysis of Kunzite;* by R. O. E. DAVIS.

AT the request of Professor Charles Baskerville, Director of the Chemical Laboratory, I undertook the chemical analysis of kunzite, the new and beautiful variety of spodumene, described by Kunz and himself.* The methods used were those given in Hillebrand's excellent "Principles of Rock Analysis" † and need not be re-stated here.

A selected, clean, deep lilac-colored crystal, quite free from flaws, was ground to an impalpable powder and used in the analytical work. Following are the figures obtained:

	Percent.
SiO_2	64·05
Al_2O_3	27·30
NiO	0·06
MnO	0·11
ZnO	0·44
CaO	0·80
MgO	none
K_2O	0·06
Na_2O	0·30
Li_2O	6·88
Loss on ignition	0·15
Total	100·15

No chromium, vanadium, titanium, iron, strontium, barium, thorium, zirconium or phosphorus was found. On account of the unique properties possessed by the mineral the other rare earths were looked for. Dr. W. J. Humphreys, of the Rouss Physical Laboratory of the University of Virginia, kindly photographed the arc spectrum obtained from the material which had been freed from silicon and lithium. He reported none of the characteristic lines of cerium and yttrium groups present. The material lost its pink color on ignition.

University of North Carolina.

* See the preceding paper; also Science, xviii, 303 and 769, 1903.
† Bulletin of the U. S. Geological Survey, No. 176.

ART. VI.—*The Occurrence of Celestite near Syracuse, N. Y., and its Relation to the Vermicular Limestones of the Salina Epoch*;* by EDWARD H. KRAUS.

LAST summer, while conducting a field excursion with a class in geology from the Summer School of Syracuse University along the new Jamesville branch of the Syracuse and Suburban R. R., the mineral celestite was noticed. Although Dana† and Whitlock‡ mention Syracuse as a locality for celestite, I have been unable to find the original source§ for such a reference. Neither Cleveland‖ nor Beck¶ refer to Syracuse in this respect. This, therefore, is the first time that a detailed description of this occurrence of celestite is given.

This mineral was first found about three-quarters of a mile north of the village of Jamesville, near where the electric railroad crosses the turnpike to De Witt. At this point quite a heavy grade is encountered by the railroad and a considerable amount of rock—the drab limestone of the Salina epoch—had to be removed in order to allow the railroad to run parallel to the turnpike for about three-quarters of a mile. The cut varies from about two to six or eight feet in some places. In the rock which was removed, and also along the sides of the cut, the fresh mineral was found in a surprisingly large quantity.

The mineral does not occur in veins or cavities, as might be supposed and as is usually the case, but it is found disseminated throughout the rock. The character of the dissemination varies greatly with the locality and horizon in which the celestite is found. Three distinct types of dissemination were noticed. 1. In some cases the mineral has had ample time to assume well-defined crystal forms, which may in many instances be from one-half to one inch in length. This type of dissemination is shown by figs. 1 and 2. 2. In other places the crystallization was more rapid, and many crystals of a smaller but practically uniform size, one-eighth to three-eighths of an inch, resulted. Fig. 3 shows this type of dissemination;

* Read in abstract before the Onondaga Academy of Science, February 19, 1904.

† Dana, System of Mineralogy, 6th edition, 1892, 1063.

‡ Whitlock, New York Mineral Localities, New York State Museum Bulletin No. 70, 1903, 54.

§ Whitlock in a letter to me, concerning the mentioning of Syracuse as a locality for celestite by Dana, who is his authority, says: "It is possible that the notice of this locality was communicated by some local observer." This would, of course, account for the fact that nothing published can be found.

‖ Cleveland, Mineralogy, 1822.

¶ Beck, Mineralogy of New York, 1842.

the fresh mineral can be seen to the left. 3. The mineral may also occur disseminated not in the form of well-defined crystals but rather in small circular spots, which in some cases are about uniform in size, while in other instances

1 2

they may vary from three-sixteenths of an inch down to a needle-point. Figure 5 illustrates this occurrence of the mineral. No doubt the crystallization was so rapid that it was impossible for the mineral to assume well-defined forms.

3

In the first two types of dissemination the orthorhombic character of the crystals is very easily recognized. The mineral is also characterized by a slight blue tint.

Numerous attempts were made to isolate crystals so as to make goniometric measurements. In every case, however, the crystal faces were dull and gave no reflections whatever. The

various faces could, nevertheless, by means of the cleavages parallel to the basal pinacoid and the unit prism, be determined with considerable accuracy. A very common combination of faces consists of the unit prism, *m* (110); macrodome, *d* (102); brachydome, *o* (011); and the brachypinacoid, *b* (010), and the basal pinacoid, *c* (001). This combination is a usual one with celestite.

4 5 6

The specific gravity of this celestite was determined by means of a Jolly balance of the Linebarger pattern. The mean of several determinations was found to be 3·958. This agrees very closely, indeed, with the normal specific gravity, 3·962, as given by Kopp.* The mineral not only conforms to the physical properties of celestite, but to the qualitative chemical as well. I shall report later as to the quantitative chemical composition.

As already indicated, the mineral was first found near where the electric railroad crosses the turnpike to De Witt. It occurs here in what Vanuxem calls the "Magnesium Deposit." Vanuxem† divides the Salina epoch into four divisions or deposits. He says: "The first or lowest deposit is the red shale, showing green spots at the upper part of the mass. Secondly, the lower gypseous shales, the lower part alternating with the red shales, which cease with this mass. Thirdly, the gypseous deposit, which embraces the great mass quarried for plaster, consisting of two ranges, between which are the hopper-shaped cavities, the "Vermicular Limerock" of Eaton, and other porous rocks. Fourthly and lastly, those rocks which show groups of needle-form cavities placed side by side, caused by the crystallization of sulphate of magnesium, and which may from that circumstance be called the 'Magnesium Deposit.'" The "Magnesium Deposit" is included in the "Gypseous Shales" of Luther.‡ The celestite is, however, not confined to the "Magnesium Deposit," for it was also observed in other localities in Vanuxem's "Third Deposit." I was subsequently

* Naumann-Zirkel, Elemente der Mineralogie, 13th Auflage, 1895, 549.
† Vanuxem. Natural History of New York, Third District, 1842, 95.
‡ Luther, Economic Geology of Onondaga County, 264.

able to observe celestite in many places southeast of Syracuse, principally, however, at Dunlop's quarry and in the vicinity of the Rock Cut on the D. L. & W. R. R. Later, Prof. T. C. Hopkins of Syracuse University noticed it near Split Rock in the drab limestones of the Salina along the cuttings of the new Auburn and Syracuse railroad. Although I was unable to make an exhaustive study last fall of its distribution, I do not doubt, whatever, but that its occurrence in the disseminated condition, as shown by the accompanying figures, is just as extensive in the limestones of the Salina elsewhere, as in the vicinity of Syracuse.

Beck in his "Mineralogy of New York"* says: "Celestite is usually associated with limestones, but that it does not seem to be peculiar to any geological epoch." He mentions but one occurrence in the dark Salina limestone, which is on the Owasco Outlet, near Auburn. Whether the mineral occurs in this locality disseminated throughout the rock, or in cavities and veins, neither Beck nor Whitlock† states with definiteness. From the general description which they give, one is led to believe that at this locality it is of secondary formation, that is, in veins or cavities. All the other occurrences in New York State which are mentioned by Beck and Whitlock (there are nine (9) of them) are in other epochs and without an exception secondary formations.

The occurrence at Dunlop's gypsum quarry, about one-half to three-quarters of a mile to the northeast of the locality where celestite was first found, is extremely interesting. It was impossible for me during my visits to this quarry to observe the rock containing the celestite *in situ* on account of the fact that the strata above the gypsum were for the most part covered with soil or other earthy material. The dump piles, however, contain a great many rock fragments, which show large quantities of the fresh mineral. The specimen shown in fig. 3 is from this locality. The crystals are rather small, one-eighth to three-eighths of an inch in length and, where the rocks have been exposed to the weathering agencies, the crystals on the outside have entirely disappeared, leaving very unique cavities. The cavities, nevertheless, betray by means of their distinct outline what the original material was, for the orthorhombic character as well as the various faces may be easily recognized. These cavities might at first sight appear to be bird tracks or something of that character, but as said, it can be easily shown that they are crystal cavities. That this is the case can be proven beyond a doubt by breaking the specimen, as has been done in fig. 3, and we find that the mineral is

* Page 210.

† Whitlock, New York Mineral Localities, 1903, 22.

still present in the interior—to the left—in well-defined crystals, while on the outside, as a result of leaching, only the crystal cavities are to be seen.

Several specimens from the first locality show very large cavities, and their resemblances to the impressions made by chisel points does not seem to be farfetched. Figs. 7 and 8 show such "impressions" or cavities on the outside, while in figs. 1 and 2 the fresh mineral can be seen in the interior of these same specimens. Cavities of this character were noticed by Eaton, Vanuxem and others, for Vanuxem* says: "Near

7 8

Syracuse, at the Hopper locality in Onondaga Valley, and at Chittenango and so forth, surfaces are seen which show an angular configuration, somewhat resembling those leaves whose ribs are straight, and incline at an angle of about 35° from the stem. These were first noticed by Prof. Eaton in his survey of the Erie Canal, having seen some which were thrown out in digging a well at Syracuse, the cause of which was rightly referred by him to crystallization."

Vanuxem further says: "On the canal, near Lake Sodom, layers of a similar kind but belonging to a lower deposit show numerous cavities not unlike those made by a small chisel of about three-quarters of an inch in width; some of them single, and others cross each other as though struck at random. In the surface also of the calciferous slate above the gypseous deposit at Crill's in the town of Stark, there are small impressions in relief, the best defined of which are like obtuse Indian arrow heads, being triangular with their sides somewhat curved; these were previously noticed but not their forms." From this general description given by Vanuxem and also from the fact that Crill's farm in the town of Stark, Herkimer

* Vanuxem, Natural History of New York, Third District, 1842, 109.

County, is given as a locality for celestite by Beck and Whitlock, there is little doubt in my mind but that the investigators, mentioned above, had encountered specimens of the same character as those shown in figs. 7 and 8, and that the cavities and "impressions" were once filled by the mineral celestite, which was removed in the manner already referred to.

The third type of dissemination, referred to above, that is, in the form of small circular particles, as illustrated by fig. 5, is exceedingly instructive. When a rock which contains celestite in this form of dissemination is leached, it gives rise to a rock which appears as though it were worm-eaten. The lower portion of figure 5 shows the effect of such leaching and possesses a distinct porous structure. There is a very striking similarity between such a rock and the so-called "Vermicular Limestone" of Prof. Eaton and the older reports. This resemblance is shown very clearly in figs. 4, 5, 6; figs. 4, 6 being the so-called "Vermicular Limestone."

As regards the character of the rocks of the upper portion of the Salina, which contain the celestite, and which to some extent comprise the vermicular limestones, Luther* says: "The gypseous shales consist of fine-grained magnesium or dolomitic limestones in thin layers, masses of gypsum and gysiferous shale in two courses, separated by a bed of limestone forty to fifty feet thick. In the thicker and more compact layers of limestone, freshly broken blocks show the rock to be very dark, almost black in the interior, but after exposure the color changes to an ashen gray or medium dark drab, sometimes showing a slight pink shade. It is very much like hydraulic limestone in appearance, but the proportion of clayey admixture is so large as to injure or destroy its cohesive qualities. In the middle and lower beds it is frequently more or less porous or cellular. The cavities are sometimes an inch or more in diameter, very irregular and ragged in shape, and lined with a fine brown dust. When of this character, they are very unevenly distributed through the rock and most frequently are found on the surface of a layer or opening into a joint." (Compare with figs. 7, 8.)

"In other layers, the cavities are found to be much more numerous, occupying in the aggregate nearly one-half the space of the rock, and having the form of circular cells, with the diameter ranging from a quarter of an inch down to a needle-point. Usually the cells in a particular layer of limestone have a considerable degree of uniformity in shape and size, but occasionally the contrary is the case. They are smaller in the lower beds. *These cellular limestones are the 'Vermicular Limestones' of the older reports.*" See figs. 4 and 6.

* Luther, Economic Geology of Onondaga County, 264.

These "Vermicular Limestones" have given geologists much trouble as to a satisfactory explanation of their porous structure. Vanuxem speaks of the cause of their porous character in the following language: "The cells show that parts of the rock were disposed to separate into very thin layers, which project into the cells, an effect wholly at variance with aëriform cavities, whose removal caused the cells in question. This view appears to be fully confirmed by the discovery in this rock of those forms which are due to common salt, showing that a *soluble saline material* had existed in it, had acquired shape in the rock, and had subsequently been dissolved, leaving a cavity or cavities."* The discovery at Livonia, N. Y., of such a cellular rock filled with salt seems at first to support Vanuxem's theory to a very considerable extent. Of this rock filled with salt, Luther† says: "In the shaft sunk to the rock salt beds at Livonia, N. Y., at the depth of 1,396 feet, thirteen feet above the salt bed, a stratum of the cellular, magnesium limestone was reached, in which the cells were filled with salt. A large block was placed in a running brook, and in a few hours the salt had been dissolved out, leaving the rock in precisely the same condition that it presents when found in loose fragments or in the outcrops in this (Onondaga) County."

It seems almost impossible to conceive how the very soluble sodium chloride could be disseminated through a rock, as would be necessary to give rise to this peculiar porous structure of the "Vermicular" limestones, as is clearly illustrated by figs. 4 and 6. Certainly such a deposition of salt would not be in harmony with the now generally accepted theory of Ochsenius‡ as to the formation of salt deposits, as we find them in New York State, Stassfurt in Germany, and elsewhere. I believe that sodium chloride is an altogether too soluble salt to have been the original occupant of these many cavities of the "Vermicular Limestones."

According to Wackenroder,§ celestite is slowly, but completely, soluble in water containing sodium chloride in solution. Virck‖ says, that 100 parts of water containing 15·54 per cent of sodium chloride dissolve 0·2186 grams of strontium sulphate, which is the composition of celestite. The same authority says, that it is even more soluble in water containing magnesium chloride, and not quite so soluble in water containing calcium chloride.

* Vanuxem, Natural History of New York, Third District, 1842, 101.

† Luther, Economic Geology of Onondaga County, 1895, 265.

‡ C. Ochsenius, Die Bildung der Steinsalzlager und ihrer Mutterlaugensalze. Halle, 1877. Kemp, Handbook of Rocks, 1900, 78.

§ Comey, Dictionary of Chemical Solubilities, 1895, 455.

‖ Ibid., 1895, 455, also Chemisches Centralblatt, 1862, 402.

That many of the rocks of the gypseous shales contain, or did contain salt, is evidenced by what Luther* says: "In the beds of limestone lying between the principal gypsum deposits, and more abundantly in that underlying the gypsum beds, hopper-shaped mud casts of what are supposed to have been salt crystals are numerous. *They are found in both the cellular and non-cellular layers.*" The presence of the magnesium and calcium chlorides is easily proven by referring to the many excellent analyses of the brines of this state, as also to those of the salt manufactured from them. The following analyses† represent typical brines from the principal salt-producing sections of the state.

	Wyoming Valley	Genesee Valley	Onondaga.	
$CaSO_4$	0·3083	0·5790	0·3632	0·5440
$CaCl_2$	0·5268	0·4650	0·5701	0·1340
$MgCl_2$	0·1034	0·2125	0·2852	0·1790
NaCl	23·5819	25·3199	18·4277	18·0560
H_2O	75·4796	73·4234	80·3538	81·0870

Englehardt, Bishop and others† believe that the chlorides (magnesium and calcium) are derived from the rocks overlying the rock salt deposits. Englehardt thinks that the quantity of calcium sulphate is dependent upon the amount of these chlorides present.

These analyses show that the meteoric waters passing through the rocks of the upper portion of the Salina, since they contain sodium, magnesium, and calcium chlorides in solution, ought to, according to the authorities cited above, be good solvents of celestite. Then, if it be true that celestite can be quite readily dissolved in such a circulating water, it is not unreasonable to believe that strontium should be present in the brines of this vicinity.

Through the courtesy of Mr. John D. Pennock, chief chemist of the Solvay Process Co., Solvay, N. Y., I was able to procure a sample of the brine which that company obtains from its wells at Tully, N. Y., a short distance south of Syracuse. The brine is not formed by a true meteoric water, but according to Hazard,§ "fresh water is introduced into the wells, where it dissolves the salt, and is forced to the surface in the form of a saturated brine." It is, therefore, evident that such a brine would not show as large an amount of stron-

* Luther, Economic Geology of Onondaga County, 1895, 265.

† Merrill, Salt and Gypsum Industries of New York, State Museum Bulletin No. 11, 1893, Table of Analyses by Dr. F. E. Englehardt opposite page 38.

‡ Ibid., No. 11, 1893, 62.

§ Luther, Economic Geology of Onondaga County, 1895, 257.

tium as would be the case if the water were in contact with the limestones overlying the rock salt beds for a considerable length of time.

I am indebted to Professor F. A. Saunders of Syracuse University for a very careful spectroscopic examination of this Tully brine. The spark spectrum was produced by means of a Rowland concave grating, using a scale which was sufficient to give a visible spectrum of about fourteen inches. From the study of the negative of this spectrum, it was shown that all the characteristic lines of strontium were strongly developed, and clearly revealed the fact that strontium is actually present in this artificial brine in more than a spectroscopic trace. Not only is strontium present but a trace of barium was also noticed. After having communicated the fact that strontium is present in the Tully brine to Pennock, he was able to confirm Saunders's observation. Strontium is not indicated in the analyses of Englehardt, given above, on account of the fact that it was not tested for, and is, therefore, estimated with the calcium; hence the amount of $CaSO_4$ is necessarily a trifle too high. As to the amount of strontium, calculated as sulphate, present in the above brine, I shall report later. I have not been able, as yet, to examine the brines from the wells on the Onondaga Salt Reservation, which are formed by true meteoric waters, because the wells are shut down during the winter months.

With the following facts in mind, (1) that celestite is quite soluble in water containing sodium chloride, magnesium chloride or calcium chloride in solution, and (2) that the dissemination of celestite through the rock is not at all unlike that which would be necessary to form cavities as found in the "Vermicular" Limestones, (3) also that when such a rock has been leached the appearance of the resulting rock is exactly like that of these so-called "Vermiculars," and (4) that the brines of this vicinity do contain a considerable amount of strontium, also traces of barium, which is isomorphous with strontium and usually replaces it to a small extent in celestite, and (5) the finding in that "Vermicular," which outcrops in various places in Syracuse and vicinity, of cavities with such forms as would be produced by the leaching of celestite crystals,* we cannot but come to the conclusion *that these many cavities, now empty, in the "Vermicular Limestone" of the Salina Epoch must have once contained a mineral of the char-*

*The specimen of fig. 5, is from E. Adams St. near Irving Ave., Syracuse. A study of the cavities on the surface of this rock, which is locally known as "the vermicular," reveals those forms which are so characteristic of celestite. They are not unlike those of fig. 3, where the fresh material is still present in the interior.

acter of celestite, and that by the action of the agencies, mentioned above, the same was dissolved, leaving nothing but the so-called cells to show its former presence. I do not believe that the salt found in the rock in the shaft at Livonia, N. Y., is the original occupant of the cavities, but rather that it is of secondary formation, having been derived from the rocks above, which Luther says contain many mud casts at this locality. When the salt is leached from this rock, many of the resulting cavities show the characteristic outline of the celestite crystals and also possess that weathered appearance which is so peculiar to the cavities of the "Vermiculars."

During the coming summer I intend to continue my study of the distribution of the celestite-bearing limestones, and also the brines of the state as to the amount of strontium they contain. I will report as soon as possible.

In conclusion, I wish to thank my colleague, Mr. C. L. Hewitt, for the very valuable services he rendered in making possible the excellent illustrations which accompany this paper.

Syracuse High School, March, 1904.

Art. VII.—*A Famous Fossil Cycad;* by Lester F. Ward.

There is in the Museum of Mineralogy and Geology at Dresden a petrified trunk of a cycad that has been known for more than two centuries and a half. It is the type and only known specimen of *Cycadeoidea Reichenbachiana* (Göpp.) Cap. and Solms, the *Raumeria Reichenbachiana* of Göppert. It has the longest history of any specimen of its class, unless we count as history the thousand years or more that the type of *Cycadeoidea etrusca* lay upon an Etruscan tomb at Marzabotto before it was discovered by Count Gozzadini in 1867 and found its way in 1878 to the Geological Museum of Bologna.

When in 1894 I made a voyage to Europe chiefly for the purpose of studying the collections of fossil cycadean trunks in the various museums preparatory to the elaboration of those of America, I was not able to visit Dresden and see this specimen. In 1898 Dr. H. B. Geinitz sent me a photograph of it as it stood in the Dresden Museum resting on a wooden pedestal made to support it. This I reproduced in my memoir on the Cretaceous Formation of the Black Hills as indicated by the Fossils Plants,* explaining the circumstances in the text.† The photograph was not particularly clear and was of a light brown color, somewhat pale. The half-tone process by which it was reproduced brought out much that was latent in the photograph and the result is a considerably better view than the original. In studying this it was clear both that the petioles were descending and also that the sharp angle of the leaf scars was on their upper side, both of which features are very rare in cycad trunks. This raised the suspicion that the specimen might be inverted, and led me to remark in the footnote on page 605 of that memoir that, judging from the picture alone, "I should say that the trunk is here inverted, but to be certain it would be necessary to examine it. It is clear that in the present position the leaf scars have a decided downward direction, which is rare but not unknown (e. g., *C. Uhleri*). Moreover, the scars, which are subtriangular, have now their sharp angle upward, which, if the specimen is right side up, would indicate that the keel of the petioles was on the upper side, a condition which I have met with in only two other species, *C. aspera* and *C. insolita*."

On August 27, 1903, on my way from Vienna to Berlin, I stopped at Dresden and visited the Royal Museum. I readily found the specimen still standing upon the same support as when photographed by Dr. Geinitz. A glance at it was suffi-

* Nineteenth Ann. Rep. U. S. Geol. Surv., 1897–98, pl. lix.
† Ibid., pp. 601, 604, 605.

cient fully to justify the suspicion expressed in the above-quoted footnote, and it was clear that it stood on the somewhat even face presented by the transverse fracture through the middle of the trunk, while the much less even base, which, if the specimen had been placed in its natural position, would have required it to be supported by wedges or cement, was uppermost and distinctly showed its character as such. Dr. Johannes Victor Deichmüller, Directorial Assistant, who, in the temporary absence of the Director, was in charge of the Museum, and to whom I announced the object of my visit, was much interested in my account and kindly caused the specimen to be placed on a table where I could thoroughly examine all parts of it. I proceeded to describe it in my note-book, in which I systematically recorded all the visible features in the same manner as I have done for all the American trunks. As the specimen is regarded as constituting a species, and does, indeed, differ specifically from all others thus far known, these notes upon it form an adequate basis for the specific description. Before dealing with the systematic part, however, it will be of interest to give a somewhat detailed historical account of the specimen.

I. *History and Literature.*

Desiring to learn the authentic history of the discovery of this specimen and its removal to the Dresden Museum, I wrote to Dr. Deichmüller on my return to America, giving him such bibliographical references as I was able to find and requesting him to consult if possible the original publications. He was successful in finding the most important of the early documents, namely, the report of Christian Heinrich Eilenburg, who was the Director of the Dresden Museum at the time this specimen was acquired. It is printed in German and French and bears the following title:

Kürzer Entwurf der Königlichen Naturalienkammer zu Dresden. Dresden und Leipzig, in der Waltherischen Buchhandlung, 1755.

oder:

Description du Cabinet royal de Dresde touchant l'histoire naturelle. A Dresde et à Leipzig, chez George Conrad Walther, libraire du roi, 1755.

Dr. Deichmüller had the great kindness to copy out of this work and send me the following passages relating to the object under consideration:

"A large case in the sixth arcade contains petrifactions from the vegetable kingdom, which always fixes the attention of connoisseurs. That which is most admired here is a magnificent

block of petrifactions which M. Borlach, Counsellor of Mines, sent us from Poland. It weighs over 100 pounds, and is, in our opinion, only a mass of petrified Hippurites, or coral-cups, although a celebrated naturalist entertains the view that this superb mass may be the summit of a palm tree turned to stone." (P. 23 of the French and p. 24 of the German).

Dr. Deichmüller also found in the library of the Dresden Museum the original manuscript catalogue in Eilenburg's handwriting and never published, bearing the title: "Lithoxylorum seu lignorum petrefactorum varii generis variæque speciei Catalogus Novus in quo simul osteocollarum et lignorum fossilium præsens collectio indicata est a Christiano Henrico Eilenburgio, MDCCLIII." On page 41 of this catalogue occurs the following entry written in Latin: "No. 76. A segment certainly of petrified palm wood, the fibers and stems so distinct that they would be taken for combustible wood unless the contrary is shown by handling and weighing. A certain projecting knot surrounded by regularly arranged natural rows and fibers calls for special attention in this remarkable petrifaction; but the structure is the same above and below and such that we are able to see that it penetrates through the entire thickness of the trunk. From Poland."

The specimen was first figured by George Wolfgang Knorr in his well-known "Sammlung von Merkwürdigkeiten der Natur und Alterthümern des Erdbodens oder versteinte und andere gegrabene Cörper in illuminirten Kupfertafeln," of the text for which he only lived to write the first fascicle of 36 folio pages (Nürnberg, 1755). This did not include the description of this specimen. The remainder of the text was written by Johann Ernst Immanuel Walch, and published as a separate work with the title: Die Naturgeschichte der Versteinerungen zur Erläuterung der Knorrischen Sammlung von Merkwürdigkeiten der Natur, Nürnberg, Erster Theil, 1773, Zweyter Theil, Erster Abschnitt, 1768, Zweyter Abschnitt, 1769, Dritter Theil, 1771, Vierter Theil, 1773. This work is usually preceded by Knorr's fascicle and accompanied by the atlas as a separate volume, the whole being known as the work of Knorr and Walch. The plates of the atlas are numbered in an almost incomprehensible manner, but the figure occurs on Plate III*a* of the Supplement, which is really the 220th plate of the work, of which it is figure 6. No one who has seen the specimen would ever recognize this as being a figure of it, as it does not show either the shape or the markings at all correctly.

In Walch's description of it, which occurs on pages 150–152 of the third part, nothing is said of the defects of Knorr's figure, and he confines himself to a general treatment of the specimen. He quotes extensively from what he calls "Rath

Eulenburg's Beschreibung der Dresdner Naturalien-Cammer," especially, p. 24. This work is therefore apparently the same as that of which Dr. Deichmüller has furnished me the title, but it seems to contain much additional information relative to this specimen. From the account here given and from all other available sources we learn that the specimen was found in 1753 by a man named Schober in a swamp near Lednice, a small village in the salt region, about three miles E. S. E. of Wieliczka, in Galicia, and therefore only about fifteen miles in nearly the same direction from Cracow. This swamp is said to lie 500 feet above the level of a small stream, tributary of the Weichsel, which flows through that country within a mile of the spot. It was not, however, supposed that this swamp was the original source of the cycad, as there are no rocks near there and the formation consists of simple clay soil. It was supposed therefore that it had been brought there by the peasants who were accustomed to utilize the swamp in macerating their hemp. But there was said to be some higher ground not far distant where there are hard rocks, and where, in fact, a small piece was found resembling the cycad in structure. If so this is probably the source of the latter.

A mining engineer named Borlach in some way obtained possession of the specimen and sent it to Dresden, where it was placed in the Natural History Cabinet which has developed into the present Museum of Geology and Mineralogy, occupying the southwest portion of the Zwinger. Borlach left manuscript notes with the specimen giving most of the above-mentioned details and also indulging in some speculations as to the nature and significance of the specimen, which are tolerably free from the crudities of most of the discussions of his time relative to this class of objects. He queries, for example, whether it is a marine plant, or the nest of some marine animal, or a petrified land plant such as the top of a palm tree. He seems to incline to the last of these suppositions, but says that if it really be a petrified palm the climate must have been hot at the time it grew, from which he infers that the earth must have changed its axis since that time. It is probable that Borlach is the person to whose opinion to this effect Eilenburg refers in the passage quoted above from his report.

Eilenburg describes the specimen in considerable detail, says that it is irregularly broken at both ends, has a cylindrical but somewhat oval shape, is 22 inches in major and 20 inches in minor diameter and 24 inches high, is of a black color, though brownish at one end, has the hardness of agate or flint, and takes a fine polish. If a small piece be detached and thrown into the fire it becomes ash gray and gives off the odor of brimstone, but remains firm and does not burst like other hard

stones. He describes the surface of the specimen as covered with holes somewhat systematically arranged, sometimes in groups having the shape and size of a walnut, except that in some cases there rises in the middle on the longer side a rounded boss [this must refer to the reproductive organs]. The areolæ are described as oval and penetrating two to three inches into the stone, diminishing in size with the depth. But in some, he says, there is a nucleus [leaf base] of the same material as the rock, except that it possesses small longitudinal pores. Besides the larger cavities there are other much smaller ones of the size of a pea arranged in elliptical concentric groups, some of which are compressed [bract scars]. In some places are to be seen special growths, so to speak, having the form of buds which have not yet opened and only slightly project. Some of these smaller cavities have porous nuclei resembling grains of barley, but most of them are empty. In one spot on this rare petrifaction, he adds, a piece of the rock has fallen out leaving a funnel-shaped depression two to three inches deep, the sharp end being directed toward the axis.

Eilenburg, as we have seen, adopted the view that the petrifaction represented a hippurite or coral, but at that day these objects were referred to the vegetable kingdom.

On page 150 of Walch's work it is stated that the specimen was found in 1751, but on the next page it is said in Borlach's notes that it was found "erst in diesem Jahre." As all accounts agree that it was sent to Dresden by Borlach in 1753, this would also seem to be the date of its discovery. It is, however, possible that Borlach wrote these notes two years earlier.[4]

Dr. Deichmüller finds a note appended to the entry above quoted in Eilenburg's manuscript catalogue, which reads as follows: "We take pleasure in referring in this connection to the able work of P. Gabr. Rzaczynsky: *Historia naturalis curiosa regni Poloniæ*, 1721, printed at Sandomir, where on pages 5–117, is to be found a more complete account of the petrified wood (*Lithoxylis*) discovered in Poland." From this entry Dr. Deichmüller thinks it not impossible that this specimen may be treated in Rzaczynsky's work as early as 1721. This does not seem probable from the above account, but it is greatly to be hoped that this work may be found and examined from this point of view.

The specimen lay in the Dresden Museum for nearly a century without receiving further attention. In 1844 Göppert seems to have already named and described it, for in his contribution to the second edition of Wimmer's Flora von Schlesien, vol. II, p. 217, where he describes the genus Raumeria and names *R. Schulziana* (found near Gleiwitz in Silesia), he adds a note in which he says that "the celebrated

cycadean trunk at Dresden belongs to the same genus (*Raumeria Reichenbachiana* Göpp. manuscript)." It was, however, nine years before the description and illustration appeared. Meantime Unger listed it in his Synopsis Plantarum Fossilium, 1845, p. 163, and in his Chloris Protogæa of about the same date, p. LXV. Göppert also put the name in his list contributed to Bronn's Handbuch (vol. II, Abth. II, Th. III, Index palaeontologicus, 1848), both in the Enumerator, p. 38, and the Nomenclator, p. 1078, referring it to the lower "Molasse" or Miocene. The naked name occurred at least four times more, viz., in Unger's Genera et Species Plantarum Fossilium, 1850, p. 301; in the same author's work: Die Pflanzenwelt der Jetztzeit in ihrer historischen Bedeutung, 1851, p. 230; in Massalongo's Conspectus Floræ Tertiariæ Orbis Primævi, 1852, p. 12; and in Giebel's work: Deutschlands Petrefacten, 1852, p. 91; before Göppert's descriptive paper: Ueber die gegenwärtigen Verhältnisse der Paläontologie in Schlesien so wie über fossile Cycadeen, in which the specimen was fully treated, finally appeared in the Jubiläums- Denkschrift der schlesischen Gesellschaft für vaterländische Cultur, Breslau, 1853, pp. 251–265, pl. vii–x.

In this paper we have a somewhat adequate description of the specimen accompanied by five figures (pl. viii, figs. 4–7; pl. ix), which, Göppert says, were furnished by Geinitz. He dedicates the species, however, to Reichenbach, long Director of the Dresden Museum, who, he says, had always afforded him free access to the collections. From this we must infer that he had studied the specimen himself at first hand. His historical account is very brief, referring chiefly to Walch's description, but making no mention of Eilenburg's.

He says that the trunk is cylindrical, 24 inches high, 20–22 inches in diameter, transformed into an entirely black, chert-like mass, showing very little structure. He classes it as the trunk of a cycad and compares it with that of *Cycas revoluta*, reproducing for comparison Vrolik's figure of a somewhat remarkable specimen of that species (pl. x, fig. 3). He also compares, or rather, contrasts it with *Cycadeoidea microphylla* of Buckland, reproducing (pl. x, fig. 2) his figure in the Bridgewater Treatise, vol. II, pl. lxi, fig. 1. He recognizes the scars as those of the petioles, and says some are from one to two inches deep. The prominent reproductive organs could not, of course, have failed to attract his attention, and he refers to them as the small scars that take the place of the large ones and arrange themselves in circular or elliptical groups, which he regarded as perhaps representing spots where buds are breaking through. Such buds, he says, really seem to have been present here. He seems to have no idea of their being

reproductive organs, and compares them with those of both *Cycadeoidea microphylla* and *Cycas revoluta*, saying that as the buds grow out branches are formed.

The principal figure of the trunk (pl. viii, fig. 4), furnished, as he says by Geinitz, represents, about one-eighth natural size, the side opposite to that shown in the photograph sent me by Geinitz. The specimen here stands more erect, and though inverted shows less of the base. Fig. 5, which Göppert calls the "obere Querschnitt," is a view of the base, and the structureless area on the upper left portion represents a large oblique fracture, which I described as the loss of a "large piece extending to the medulla and running out 28^{cm} above, with a width of 43^{cm}." Plate ix represents natural size an area 20^{cm} wide and 215^{mm} high near the base, which is still at the top of the figure, showing several of the larger reproductive organs, one of which, though here drawn as if the spadix had fallen out, is of special interest in showing a radiate structure with carpel-like partitions that may contain seeds.

Plate viii, figs. 6 (natural size) and 7 (somewhat enlarged) represent a cross section of a small piece from this trunk, apparently a leaf scar containing the base of a petiole, which Göppert says was sent him by Reichenbach at an earlier date, and which he seems to have cut transversely and figured himself. He recognizes resin ducts and parenchymatous cells, but finds no vascular bundles. I was myself unable to see any vascular bundles in the leaf bases. They are either indistinguishable from the parenchyma or else they lie close to the walls and blend with the partition lines.

In 1858 Geinitz issued one of the reports on the Dresden Museum which bear the title: Das Königliche Mineralogische Museum in Dresden, in which he gave a succinct history of the Museum from its earliest beginnings. It does not, however, contain any of the above facts relative to this specimen, which is only once mentioned (p. 17), in connection with the great three days' fire of 1849, during which the greater part of the collections thus far accumulated were destroyed. "Only one specimen, the precious *Raumeria Reichenbachi* Göppert, a cycad from Wieliczka, remained unscathed under the protection of a sandstone pillar."

The next mention that I find of this species is in Miquel's Prodromus Systematis Cycadearum, published at Utrecht and Amsterdam in 1861 (p. 29). It adds nothing to the knowledge of it.

Equally without significance is the allusion to it by Geinitz in his Dyas (Heft II, 1862, pp. 148, 341), except for his reference of it to the Permian, which was only a guess and of course a wrong one.

Carruthers in 1870 described the species twice in his well known paper on Cycadean Stems from the Secondary Rocks of Britain (Trans. Linn. Soc., vol. XXVI, pp. 682, 704), but does not appear to have seen the specimen. He says that the formation is unknown. Schimper also described the species in 1870 (Paléontologie Végétale, vol. II, p. 189), but he distinctly stated that he had not seen the fossil and could only copy Göppert's diagnosis.

Geinitz, in his report on the Dresden Museum bearing the same title as the one previously mentioned, but dated 1873, gives a short bibliography but, as it seems, inadvertently omits the title of Göppert's paper above treated, in which this specimen was first described. This omission he supplies by publishing a supplementary page dated January 12, 1874. This he was kind enough to send me at the same time as the photograph.

Count Solms-Laubach examined this trunk and was the first to point out that Göppert's whorls of small scars represent the lateral fruit-bearing axes (Einleitung in die Paläophytologie, Leipzig, 1887, p. 102). He did not therefore hesitate to class it as a Bennettites as Carruthers had defined that genus.

In 1892 Capellini and Solms-Laubach referred this species to Buckland's genus Cycadeoidea (I tronchi di Bennettitee dei Musei Italiani, Mem. Real. Accad. Sci. dell' Ist. di Bologna, Ser. V, Tom. II, p. 188), in which I have followed them in all my papers where I have had occasion to mention it (Proc. Biol. Soc. Washington, vol. IX, April 9, Washington, 1894, p. 85; Proc. U. S. Nat. Mus., vol. XXI, No. 1141, Washington, 1898, p. 198; Nineteenth Ann. Rep. U. S. Geol. Surv., 1897–98, Washington, 1899, pp. 601, 604, 605, pl. lix).

II. *Geological Position.*

It will be seen from the above sketch of the history of this specimen that the geological formation to which it belongs is only twice alluded to, one of the references placing it in the Miocene and the other in the Permian. That it could have come from neither of these formations I have all along been satisfied, and from its close resemblance to the trunks found in the Lower Cretaceous of other parts of Europe, and especially of America, I have believed that if its true source should ever be discovered it would be found to be in beds of that age. As it was found in territory now forming a part of the Austrian empire, and as geological activity in Austria has been very great for many years, I hoped to find that the region around Lednice had been surveyed in a manner sufficently thorough to furnish the data for forming a judgment as to the true age of the beds in which it occurred. After some unsuccessful search among the voluminous reports of the Austrian Geological Survey, I

finally wrote to Dr. Emil Tietze, the distinguished Director of the k.k. geologische Reichsanstalt, to learn if possible whether this district had been surveyed and if so where I could find the report, maps, etc., He replied promptly and informed me that he had himself made this survey and published the results in 1887.*

In my letter to Director Tietze, dated November 12, 1903, I said:

"I note that most of the region about Cracow is mapped as Tertiary. It does not seem probable that the specimen could have come from the Tertiary, as all similar trunks, from whatever part of the world, have been found in much older strata, ranging from the Middle Jurassic to the Lower Cretaceous. The specimens most closely related to it in America occur in the Lower Cretaceous of the Black Hills, South Dakota."

In his reply of December 10, he says:

"The salt formation of Wieliczka is certainly Tertiary and Miocene. The *Cycadeoidea Reichenbachiana* surely does not come from this salt formation, the flora of which is in fact known from the works of Unger and Stur. But at Lednice the beds of the Miocene salt formation do not occur. There are developed partly Oligocene, partly Lower Cretaceous deposits. Probably, therefore, the specimen in question came from the Lower Cretaceous of Lednice. Still, I must admit that thus far the presence of fossil plants was not known here, and also that in the general region about Wieliczka such remains have heretofore scarcely been found. This is of course no reason for doubting their presence at this locality."

A glance at the fourth sheet of Dr. Tietze's Map (Jahrb. 1887, pl. xix), shows that beds colored for Neocómian occur at Lednice and throughout that general region, and it seems therefore next to certain that it was from these beds that the specimen was primarily derived.

III. *Systematic Treatment.*

Description of the Species.

Cycadeoidea Reichenbachiana (Göpp.) Cap. and Solms.

1755. Hippuriten oder versteinerte Corallenbecher Eilenburg: Kürzer Entwurf der Königlichen Naturalienkammer zu Dresden, p. 24.

1771. Vegetabilische Versteinerung Walch: Die Naturgeschichte der Versteinerungen zur Erläuterung der Knorrischen Sammlung von Merkwürdigkeiten der Natur, Pt. III, p. 150; Atlas, Supplement, pl. III*a*, fig. 6.

* Die geognostischen Verhältnisse der Gegend von Krakau. Von Dr. Emil Tietze. Jahrb. d. k.k. Geol. Reichsanstalt, XXXVII. Bd., 1887, Wien, 1888, pp. 423-838. 4 maps.

1844. Raumeria Reichenbachiana Göppert in Wimmer: Flora von Schlesien, Ed. II, vol. II, p. 217 (nomen).
1853. Raumeria Reichenbachiana Göpp.: Jubiläums-Denkschrift d. Schles. Ges. f. vat. Cult., p. 262, pl. viii, figs. 4–7; pl. ix.
1892. Cycadeoidea Reichenbachiana (Göpp.) Cap. and Solms: Mem. Real. Accad. Sci. Ist. Bologna, Ser. V, Tom. II, p. 188.
1894. Cycadeoidea Reichenbachiana (Göpp.) Cap. and Solms. Ward: Proc. Biol. Soc. Washington, vol. IX, p. 85.
1899. Cycadeoidea Reichenbachiana (Göpp.) Cap. and Solms. Ward: Nineteenth Ann. Rep. U. S. Geol. Surv., 1897–98, pp. 601, 604, pl. lix.

Trunks large, cylindrical or subconical, little compressed, the longer diameter 54^{cm} at the base and 52^{cm} near the middle, the shorter 44^{cm} at the base and 42^{cm} near the middle, unbranched; rock very hard and chert-like, black, becoming light gray on long exposed surfaces, fine-grained, breaking with a conchoidal fracture, of high specific gravity; organs of the armor all slightly and uniformly ascending; phyllotaxy much interrupted and irregular but consisting of two spiral rows of which those from left to right form an angle of about 45°, and those from right to left of about 25° or 30° with the axis, the former much more clear; leaf scars subrhombic, the lower angle obtuse, the two upper sides commonly reduced to a curve or arch, somewhat uniform in size, averaging 25^{mm} in width (but showing extremes ranging from 15^{mm} to 30^{mm}) and 13^{mm} in height showing extremes from 10^{mm} to 20^{mm}; leaf bases usually visible at the bottom of deep areolæ, the depth varying from 2^{cm} to 6^{cm}, probably all disarticulated at a natural joint, the somewhat spongy or porous interior inclosed in a sheath of firm, fine grained material which itself consists of two plates, the two together about $0{\cdot}5^{mm}$ thick; vascular bundles invisible, perhaps inclosed between the two plates of the sheath; walls very thick but varying from 2^{mm} to 15^{mm}, averaging about 1^{cm}, rough and irregularly grooved on the outer surface, sometimes showing a median line, often traversed by bract scars; reproductive organs very large, numerous and prominent, distorting the arrangement of the leaf scars, elliptical in cross section, the longer axis often 7^{cm} or 8^{cm}, the shorter 4^{cm} or 5^{cm}, but varying greatly in size and sometimes appearing to coalesce; involucral bract scars numerous and conspicuous, covering most of the surface of the trunk, spirally arranged around the spadices but straggling out over the surface of the walls, semilunar, triangular or subrhombic, rather small (3^{mm} to 6^{mm} long, 1^{mm} to 3^{mm} wide); central portion of the inflorescences often covered with scars or markings, sometimes solid and raised 1^{cm} to 2^{cm} above the general surface, a few concave and showing a radiate

carpellary structure suggesting the presence of contained seeds; armor very thick (5^{cm} to 10^{cm}), its attachment to the axis obscure and apparently indefinite; woody cylinder about 8^{cm} thick, uniform in color and texture and showing on the rough fractures no subdivisions or rings; medulla about 13^{cm} in diameter and nearly circular in cross section, hard, black, and homogeneous in structure, which differs little in appearance from that of the wood.

The only specimen of this species known is the one in the Dresden Museum of which the history is here recorded. It consists of the basal portion of a very large trunk of unknown height and of which the exact form of the upper part is also of course unknown, but from analogy with the hundreds of specimens of cycads which are now known from different parts of the world, it is tolerably safe to infer that the specimen represents at least half the length and that the top was conical or dome-shaped. The fracture through the middle portion is a little oblique so that the specimen leans somewhat. It is nearly even, but not wholly so, the central part of the piece preserved being somewhat higher than the part next to the surface so as to make it slightly arched or convex in the middle, sloping gently away from the center in all directions, the elevation amounting to about 4^{cm} or 5^{cm}. The specimen seems to have always been placed on this square end, apparently for no better reason than that it would thus stand without having to be blocked up, as would have been necessary if it stood on its much less even base. The base, as shown by the figures, is imperfect from the loss of numerous chips and splinters on one side and of the large piece on the other to which mention has already been made (supra, p. 46).

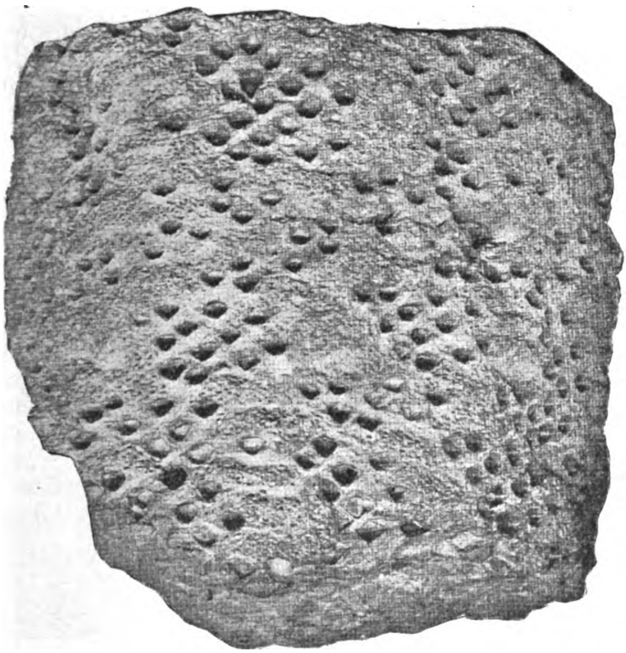
The specimen has not been weighed so far as known unless this was done soon after it was sent to Dresden, and if so the exact weight was not recorded, the only reference to the weight being that of Eilenburg who says that it is "über einen Centner schwer" (ibid, p. 24), which is repeated by Walch (op. cit., p. 150). This estimate was certainly much too small, whether we make the Centner 100, 112, or 120 pounds. The specific gravity is about the same as that of the type specimen of *C. Jenneyana* and it is somewhat larger than the basal piece of that specimen, which weighs 95·26 kilograms, or nearly 210 pounds.

Of all the species known to me *C. Jenneyana* is the one that *C. Reichenbachiana* most closely resembles, but as the above description clearly shows, it is certainly distinct from that species and is probably distinct from all other species thus far described.

After having taken full notes of the specimen, from which I have been able to make the above description, I drew the spe-

cial attention of Professor Deichmüller to the most promising of the reproductive organs, and at my indication he marked several of these with red chalk. Should any one ever undertake the study of its internal structure these should be specially investigated. Of course I cannot promise that they would be found to contain seeds, but if there are any that contain them the ones so marked are likely to do so.

It is unfortunate that Count Solms was unable to make this investigation when he was studying the British and Italian trunks. In a letter that I received from him dated October 28, 1894, he said:



Cycadeoidea Reichenbachiana (Göpp.) Cap. and Solms. Dresden Mineralogical and Geological Museum.

"It is to be regretted that at the time I requested it and offered to pay the expenses of transportation and section cutting, permission to investigate the great *Raumeria Reichenbachiana* of the Dresden Museum was not granted me. Now that I am through with this work I would not expend the necessary three or four hundred marks. From the examination of a couple of small splinters broken from it I know, however, that the trunk presents well-preserved areas, and it contains a mass of inflorescences which are certainly wholly included. Geinitz has also sent me the photograph."

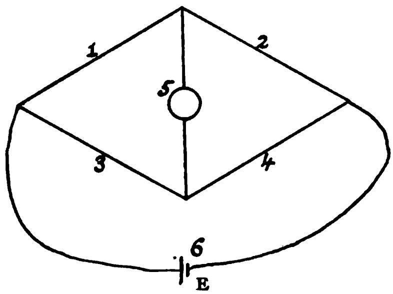
It is greatly to be hoped that Count Solms may be induced to return to this subject and to investigate thoroughly the celebrated Dresden cycad from the standpoint of its internal structure and its botanical affinities.

As the specimen has thus far always been figured inverted, I have undertaken in the figure on the preceding page to show it standing on its base. But having nothing but the reproduction of the photograph sent me by Geinitz, all that can be done is to invert this and reproduce it again. I have already stated that as it stands on the support in the Dresden Museum it leans somewhat on account of the fracture being slightly oblique to the axis. This it is sought to remedy also, and the present figure shows it erect with the scars horizontal and their acute angle downwards, as it undoubtedly grew. As the light was from above in the photograph it is of course from below in this figure, but this mechanical defect is less pronounced than it would be in most cases.

ART. VIII.—*A Comparison of Two Ways of Using the Galvanometer;* by HENRY A. PERKINS.

THERE are a number of instances in laboratory practice where a galvanometer is used to record changes in the resistance of a piece of apparatus such as a bolometer, selenium cell or bismuth spiral where the highest degree of sensitiveness is required, and there is a choice between a Wheatstone Bridge arrangement and a simple series connection. The purpose of this paper is to investigate the relative delicacy of the two methods.

In using the Wheatstone Bridge the variable resistance is introduced in one of the arms, the bridge is balanced and the galvanometer then deflects when the variable arm changes.



In order to calculate the current that will flow through the galvanometer, we apply Kirchhoff's laws, and assume the various resistances equal to r_1, r_2, r_3, r_4, r_5 and r_6, where r_6 is the resistance of the battery, r_5 that of the galvanometer and the others represent the arms of the bridge, r_1 being the variable resistance.

In calculating the galvanometer current we shall make use of the following six equations:

$$
\begin{aligned}
&(1)\ C_1 = C_2 + C_5 \\
&(2)\ C_3 = C_4 - C_5 \\
&(3)\ C = C_2 + C_4 \\
&(4)\ E = Cr_6 + C_1 r_1 + C_3 r_3 \\
&(5)\ O = C_1 r_1 - C_2 r_2 + C_5 r_5 \\
&(6)\ O = C_3 r_3 - C_4 r_4 - C_5 r_5
\end{aligned}
$$

Combining and assembling the coefficients we obtain

$$
\begin{aligned}
&C_2(r_1 + r_2 + r_6) + C_4 r_6 + r_1 r_6 = E \\
&C_2 r_1 - C_4 r_3 + C_5 (r_1 + r_3 + r_5) = O \\
&C_2 r_2 - C_1 r_4 - C_5 r_5 = O
\end{aligned}
$$

Solving for C_5 by determinants

$$
C_5 = \frac{E(r_2 r_3 - r_1 r_4)}{\sum_1^6 r_a r_b r_c - r_1 r_2 r_5 - r_1 r_3 r_6 - r_2 r_4 r_6 - r_3 r_4 r_5}
$$

Since r_1 is the variable branch $\frac{dC_5}{dr_1}$ is the measure of the sensitiveness of the arrangement. This differential reduces to

$$-E/\{2r_1 r_6 + 2r_5 r_1 + r_3 r_6 + r_5 r_6 + r_1 r_3 + r_1 r_4 + r_1^2 + (r_1^2 r_6 + r_1 r_5 r_6 + r_1^2 r_4 + r_1 r_4 r_5)/r_3 + (r_3 r_5 r_6 + r_1 r_3 r_5 + r_1 r_5 r_6)/r_4\}$$

when r_2 has been eliminated by the relation $r_1 r_4 = r_2 r_3$ which is true when the bridge is balanced.

In this equation r_3 and r_4 are independent variables, and it is now essential to find how they should be adjusted to render $\frac{dC_5}{dr_1}$ a maximum. Assuming r_3 constant and differentiating the above coefficient with respect to r_4 and setting it equal to O we obtain a value of r_4 which must be substituted in $\frac{dC_5}{dr_1}$ and the result again differentiated with respect to the one remaining variable, r_3. Finally solving for r_3 and making use of $r_1 r_4 = r_2 r_3$ and the value already obtained for r_4 we have r_2, r_3 and r_4 in terms of the constants r_1 r_5 and r_6. These values are

$$r_2 = \sqrt{\frac{(r_1 + r_6)\, r_5 r_1}{r_1 + r_5}} \qquad r_3 = \sqrt{\frac{(r_1 + r_5)\, r_1 r_6}{r_1 + r_6}} \qquad r_4 = \sqrt{r_5 r_6}\,*$$

We are now in a condition to evaluate the sensitiveness of the bridge method by substituting the values of r_2 r_3 r_4 in the coefficient of sensitiveness, reducing it to

$$\frac{dC_5}{dr_1} = \frac{-E}{r_1\{2r_5 + 2r_5^{1/2}\sqrt{(r_1 + r_5)} + r_1\}} = S_1$$

where r_6 has been set equal to O, as in either method considered it will be small compared to the other resistances, and if it is retained the above expression is too unwieldy for ready comparison with that which follows.

The second case is much simpler. Here the battery, variable resistance and galvanometer are arranged in series. Assuming here also that the battery resistance is negligible, and also using the same E.M.F. we have

$$C = \frac{E}{r_1 + r_5} \text{ and } \frac{dC}{dr_1} = -\frac{E}{(r_1 + r_5)^2} = S_2.$$

* Heavyside obtained almost the same results in the fourth paper, Vol. I. Electrical papers, but his value for r_2 is clearly wrong. It should read $\sqrt{\frac{gx(x+f)}{g+x}}$ instead of $\sqrt{\frac{gx(g+f)}{g+x}}$, as can be readily shown by applying the bridge formula to the values of r_3 and r_4 and solving for r_2. Moreover, the value of the differential coefficient $\frac{dC_5}{dr_1}$ was not given, as his method was essentially different from the one just outlined, so his paper was of little assistance.

To compare S_1 and S_2, the most obvious method is to find what conditions render them equal. Setting $S_1 = S_2$ we have $r_6^3 - 4r_1^2 r_6 - 4r_1^3 = O$. The solution of this cubic gives $r_6 = 2{\cdot}4\, r_1$, approximately. A further comparison indicates that if the galvanometer resistance is less than 2·4 times that of the cell, the series arrangement is best, although when the galvanometer resistance is zero they are again equal. All values of r_6 greater than $2{\cdot}4\, r_1$ give S_1 greater than S_2, and when $r_6 = 6r_1$ the bridge method is twice as sensitive.

The following table gives an approximate idea of the relative value of the methods. E is assumed = 100 and $r_1 = 1$. The values are given to the nearest integer.

r_6	S_2	S_1
O	100	100
r_1	25	17
$2r_1$	11	10
$3r_1$	6	7
$4r_1$	4	6
$5r_1$	3	5
$6r_1$	2	4
$7r_1$	1·6	3·4

Another aspect of the problem arises when a certain maximum current through the variable resistance is admissible. Let this current = K. Then in case of the bridge method $K = \dfrac{E}{r_1 + r_2}$ substituting for E in S_1 we have $S_1 = \dfrac{2K}{3r_1 + 4r_6}$ very nearly. In order to obtain this simple value it was assumed that in all cases where the current through r_1 arm of the bridge is limited, r_1 will be considerably smaller than r_6; and even if r_1 is half as large as r_6, the error is still very small.

Now S_2 under these conditions $= \dfrac{K}{r_6 + r_1}$ hence it is clear that the series method is always best when the current in r_1 must not rise above K.

One more case remains; when the allowable current through the galvanometer is less than that allowed through the variable resistance. In this case S_1 becomes equal to S_2 when $\dfrac{K'}{K} = \dfrac{2(r_6 + r_1)}{4\,r_6 + 3r_1}$ when K' is the maximum current allowed through the galvanometer. If $\dfrac{K'}{K}$ is smaller than this, the bridge method is clearly best. When K' is very small indeed as compared to K this method is vastly more sensitive than the other.

Trinity College, May, 1904.

ART. IX.—*Further Work with the Rotating Cathode;* by H. E. MEDWAY.

[Contributions from the Kent Chemical Laboratory of Yale University.—CXXVIII.]

IT has been shown in a previous article* that metals may be precipitated electrolytically, with great economy of time and with much exactness, by the use of a rapidly rotating cathode. The apparatus employed consists of a platinum crucible fastened to the vertical shaft of a small electric motor and dipping into the solution to be electrolyzed. A current from a series of storage batteries is passed through the solution between a platinum anode and the crucible, which serves as the cathode, while in rapid rotation; it being found that under these conditions a high density of current may be used with a consequent shortening of time over that required for complete deposition with a stationary cathode.

In the article referred to, attention is called to the rapid determination of copper, silver and nickel electrolytically. It is the purpose of the present article to give results, obtained in the same way, in a study of the conditions adapted to the use of the apparatus upon solutions in common use in the ordinary process of electrolysis between stationary electrodes, and in some cases studied by Exner† with reference to the application of the stirring anode and ordinary cathode to similar rapid precipitations.

Cadmium.

Cadmium sulphate, approximately 0·2 grm., was dissolved in 50cm^3 of water, 10 drops of dilute sulphuric acid added to give conductivity and the solution was electrolyzed, while the crucible, serving as the cathode, was rotating at a rate of 650–700 revolutions a minute. It was noticed that a perceptible solvent action of the acid takes place upon the deposit of cadmium in the short time necessarily taken to remove the crucible from the liquid. Therefore, in order to avoid siphoning, dilute ammonia was added drop by drop after the metal had been all deposited and while the current still passed, until the solution was faintly alkaline.

That this procedure proves satisfactory, the following results will show:

* Gooch and Medway: This Jour., xv, 320, 1903.
† Jour. Am. Chem. Soc., xxv, 896.

Cadmium taken grm.	Cadmium found grm.	Error grm.	Current Amp.	N. D. 100.	Time. min.
0·1088	0·1083	−0·0005	2	6·6	15
0·1088	0·1085	−0·0003	2	6·6	15
0·1088	0·1092	+0·0004	1·5	5·	15
0·1088	0·1090	+0·0002	2	6·6	15
0·1088	0·1093	+0·0005	1·5	5·	12
0·1088	0·1093	+0·0005	2	6·6	10
0·1088	0·1087	−0·0001	2	6·6	10

Tin.

For the purpose of trying the electrolytic deposition of tin, a solution of stannous ammonium chloride was prepared of about 20 cm^3 volume. To this was added a cold saturated solution of ammonium oxalate amounting to 100 cm^3. The electrolysis then proceeded in the usual way.

Results are below:

	Tin taken grm.	Tin found grm.	Error grm.	Current Amp.	N. D. 100.	Time. min.
1)	0·0804	0·0802	−0·0002	2·5	8·3	20
2)	0·0804	0·0800	−0·0004	2	6·6	20
3)	0·1607	0·1610	+0·0003	2·5	8·3	20
4)	0·1607	0·1603	−0·0004	2·5	8·3	20
5)	0·1607	0·1607	±0·0000	3·5	11·6	15

An alkaline oxalate was also used in the case of zinc—the next metal whose precipitation was attempted, but it was found expedient to use potassium oxalate instead of ammonium oxalate, since the presence of ammonium salts appeared to retard the complete deposition of the metal. Therefore, the following procedure was adopted: The zinc salt—preferably the sulphate—was dissolved in 50 cm^3 of water and 4 grms. of potassium oxalate were added. The solution was then submitted to electrolysis.

The results follow:

	Zinc taken grm.	Zinc found grm.	Error grm.	Current Amp.	N. D. 100.	Time. min.
1)	0·0553	0·0556	+0·0003	2·5	8·3	25
2)	0·0553	0·0553	±0·0000	2·5	8·3	25
3)	0·0553	0·0552	−0·0001	2·5	8·3	25
4)	0·0993	0·0995	+0·0002	2·5	8·3	30
5)	0·0993	0·0994	+0·0001	2·	6·6	25
6)	0·0993	0·0991	−0·0002	2·	6·6	25

In the usual method of electrolysis with stationary electrodes, it has been found that, when the attempt is made to remove the zinc from the platinum upon which it has been deposited, there is a coating of platinum black, some of the zinc presumably having amalgamated with the platinum. Only by dissolving the zinc, heating the crucible to redness and finally making another application of acid can this black coating be conveniently removed, there being a loss of platinum due to this removal. In order to avoid this formation it has been found necessary to coat the platinum with copper and deposit the zinc upon this. The zinc and copper may then be easily removed together by acid.

In depositing the zinc upon a rotating cathode it was found to be unnecessary to coat the platinum with copper, since the zinc could be removed without any appearance of platinum black, thus avoiding the second treatment by acid, with the attendant loss of platinum.

Gold.

The apparatus was next applied to the determination of gold. A solution of auric chloride was made of 25 cm^3 volume. Potassium cyanide was then added in considerable excess and about 30 drops of strong ammonia. The electrolysis was carried on in the usual manner.

The results are given below:

Gold taken grm.	Gold found grm.	Error grm.	Current Amp.	N. D. 100.	Time. min.
0·0695	0·0694	−0·0001	2·	6·6	30
0·0695	0·0696	+0·0001	2·	6·6	30
0·0598	0·0598	±0·0000	0·5	1·8	30
0·0598	0·0598	±0·0000	0·5	1·8	30
0·0598	0·05975	−0·00005	1·	3·3	25

No attempt was made to find the minimum time required for these depositions.

ART. X.—*On the Transverse Vibrations of Helical Springs;* by HOWARD L. BRONSON.

IT has been known for a long time that the pitch of a stretched india-rubber cord rises very little, if at all, when its length is increased by stretching. This peculiarity has been recently investigated by T. J. Baker* and by Viktor v. Lang.† Both found that the apparent constancy in pitch is in some way related to the fact that the length and tension are linearly related through a considerable range.

Now if a linear relation between length and tension is the only requisite for constancy of pitch, then certainly a helical spring ought also to have a constant pitch for a considerable change in length. This consideration, together with the fact that a metal spring ought to be more uniform in its behavior than a rubber cord, were the two things which suggested this study of helical springs.

Apparatus.

The first thing necessary for the investigation was to find suitable springs, which should have considerable range in size and stiffness. Seven springs were made of brass wire which seemed to have sufficient regularity and the desired range of size. The following table gives for each spring the diameter of wire used, the diameter of the mandrel on which it was wound, its mass, and L′, the approximate percentage increase in length for an increase in tension of ten grams.

TABLE I.

	Diam. of Wire.	Diam. of Mandrel.	Mass.	L′.
Spring 1	0·29 mm.	1·80 mm.	1·283 gr.	13
Spring 2	0·29	3·18	1·298	50
Spring 3	0·42	3·18	2·210	9
Spring 4	0·46	3·18	3·769	5
Spring 5	0·46	5·18	6·058	20
Spring 6	0·91	5·94	24·750	1
Spring 7	0·46	5·94	6·536	30

The relation between the length and tension was obtained with the spring hung in a vertical position, the lengths being read directly from a mirror scale.

The accurate determination of the frequency was the most difficult part of the work, but very consistent results were finally obtained by the use of a chronograph. The time was furnished by a clock with a seconds pendulum, which was arranged to make one contact every complete vibration. These two-second intervals were very uniform, and a comparison with the Yale

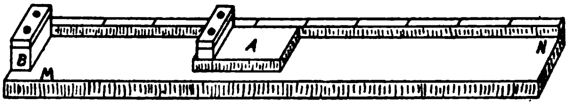
*Phil. Mag., vol. xlix.

†Wied. Ann., vol. lxviii.

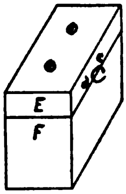
Observatory clock showed that the rate of the clock used was entirely negligible for the purpose in hand.

Figures 1, 2 and 3 show the arrangement of the apparatus for holding the spring and starting the vibrations. MN, fig. 1, is the base about 40 inches long and $1\frac{1}{4}$ inches thick. On the

1



2



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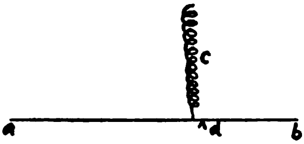

back of this is a metre scale, from which the lengths of the spring were read directly. One end of the spring was clamped to the fixed block B, the other to the movable block A.

It was found quite difficult to clamp the ends of the springs in any manner which did not have an appreciable effect on the frequency. The method finally adopted is shown in fig. 2. The last turn of the spring was drawn close up to the block by means of two fine wires fastened at *c* and *d*, which are the extremities of its horizontal diameter. These two wires were then clamped between the blocks E and F, and held the spring very firmly, yet with very little constraint.

A fine wire fastened to the center of the spring made contact with a mercury cup at each vibration. The chronograph was adjusted delicately enough to record signals with frequency as high as thirty-five per second.

In order to have uniformity in the amplitude of the vibrations, it was found convenient to use an apparatus of which fig. 3 is a diagrammatical sketch. *a b* is a wooden arm about 9 inches long pivoted at *a*; *d* is a stop which can be adjusted so that the end *b* will start the spring vibrating with the desired amplitude; the spring *c* is strong enough to release the spring without interfering with its vibration.

Observations and Calculations.

The method of making the observations in the case of springs 1, 2 and 6 was as follows:—The relation between the length and tension was determined, the tension being first increased from zero until the increase in length was no longer propor-

tional to the increase in tension, and then being decreased to zero again. Immediately after this the relation between the length and frequency was determined, starting with as short a length as possible and increasing it up to the maximum length obtained above and then decreasing it again as far as possible. The relation between the length and tension was then again obtained as in the first place. A complete set of observations for spring 1 is given in Table II.

TABLE II.

T.	Out L.	In L.	L.	Out n.	In n.	T.	Out L.	In L.
0	9·32	9·33	10	14·80	14·69	0	9·34	9·34
10	10·02	10·08	11	18·16	18·01	10	10·07	10·10
20	11·40	11·48	12	20·43	20·31	20	11·46	11·49
30	12·81	12·90	13	22·13	22·04	30	12·88	12·94
40	14·23	14·32	14	23·45	23·41	40	14·28	14·35
50	15·68	15·76	15	24·62	24·50	50	15·73	15·80
60	17·13	17·18	16	25·49	25·47	60	17·16	17·21
70	18·60		17	26·26	26·22	70	18·64	
			18	26·93				

Here T is the tension measured in grams, L is the length measured in cm., and n is the number of vibration per second. "Out" means increasing, and "In" decreasing tension or length.

The first set of values between length and tension was preliminary, taken to find the point at which the relation between the length and tension ceased to be linear. This stretching of the spring also served to remove certain very slight irregularities, as was evident when several length-tension sets were taken in succession, in which case the behavior of the spring was practically the same in all sets except the first. Therefore in making the plots and calculations the mean of the length-frequency and final length-tension sets were used, and in general only these values have been recorded in the tables.

Table III gives the mean values of L and n from Table II, also the calculated values of n and the difference between the observed and calculated values.

TABLE III. (Spring 1.)

T.	L.	L.	Observed n.	Calculated n.	Difference.
0	9·34	10	14·74	15·08	— 0·34
10	10·09	11	18·08	18·16	— 0·08
20	11·47	12	20·37	20·37	0·00
30	12·91	13	22·08	22·06	+ 0·02
40	14·32	14	23·43	23·41	+ 0.02
50	15·76	15	24·56	24·52	+ 0·04
60	17·19	16	25·48	25·45	+ 0·03
70	16·64	17	26·24	26·24	0·00
		18	26·93	26·92	+ 0·01

Figure 4 gives the length-tension and length-frequency curves plotted from the values given in Table III. The full and dotted lines represent respectively the observed and calculated curves; the observed points are surrounded by circles, and the calculated points are indicated by crosses. In case the observed and calculated curves agree too closely to show both, the calculated curve will be given, and the observed points indicated by circles.

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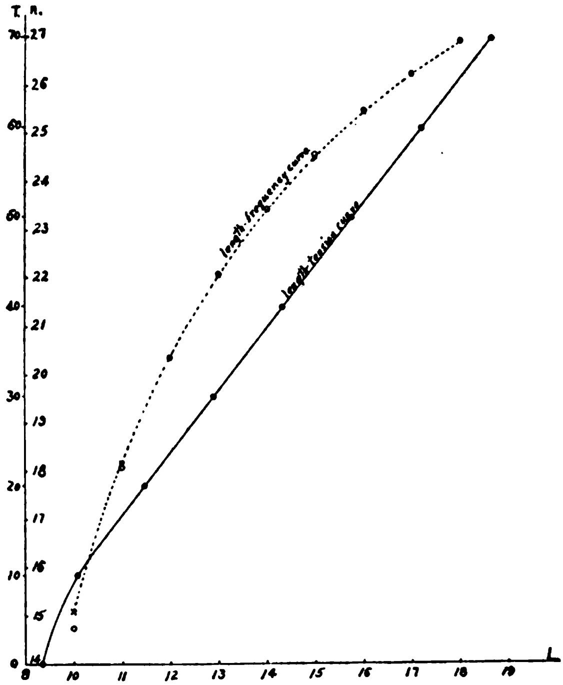

It is evident from the plot that the relation between the length and tension is practically linear through nearly the entire range used. This relation is most simply expressed by the equation

$$(1) \qquad T = mL + x$$

where m is the slope of the line, and x is the point at which, if continued, it would intersect the T axis.

In order to find the relation between length and frequency, it seemed most natural to take the usual expression for a vibrating string, which for the present purpose is most conveniently written in the form

$$(2) \qquad n = \tfrac{1}{2}\sqrt{\frac{T}{L}\,\frac{g}{M}}$$

where M is the total mass of the spring. If T is now eliminated between (1) and (2) the relation between L and n takes the form

$$(3) \qquad n = \tfrac{1}{2}\sqrt{\frac{mL + x}{L}\,\frac{g}{M}}.$$

The values of n calculated by this formula differed considerably from the observed values, as might have been expected, for in the first place the values used for T entirely ignored the weight of the spring and were therefore always too small, and in the second place the length of the spring was taken as the distance between the two blocks A and B (fig. 1), which was evidently somewhat greater than the true vibrating length. In order to avoid these two difficulties, another constant was added to equation (3). Two equations similar to (3), but with this added constant, were then used to solve for the unknown quantities x^1 and y.

$$(4) \quad \left\{ \begin{aligned} n_1 &= \tfrac{1}{2}\sqrt{\frac{mL_1 + x^1}{L_1 + y}\,\frac{g}{M}} \\ n_2 &= \tfrac{1}{2}\sqrt{\frac{mL_2 + x^1}{L_2 + y}\,\frac{g}{M}}. \end{aligned} \right.$$

Solving for y and x^1 gives

$$(5) \qquad y = \frac{N_1 - N_2 + K_2 - K_1}{4n_1^2 - 4n_2^2}$$

$$(6) \qquad x^1 = \frac{M}{g}\left(K_1 + 4n_1^2 y - N_1\right)$$

where $N_1 = \frac{mg}{M}L_1$; $N_2 = \frac{mg}{M}L_2$; $K_1 = 4n_1^2 L_1$; $K_2 = 4n_2^2 L_2$.

The value of m is always taken as the slope of the straight part of the length-tension curve; L_1, n_1, L_2 and n_2 are corresponding values of L and n taken from the length-frequency curve. The values of the constants for spring 1 are as follows:

$M = 1{\cdot}2834$	$m = 7{\cdot}00$
$L_1 = 12$	$n_1 = 20{\cdot}37$
$L_2 = 17$	$n_2 = 26{\cdot}24$

Substituting these values in (5) and (6) gives

$$y = -\ 0{\cdot}1714$$
$$x^1 = -58{\cdot}29$$

and putting these values in (4) gives the equation in its final form

$$(7) \qquad n = \tfrac{1}{2}\sqrt{\frac{\text{L}-8{\cdot}328}{\text{L}-0{\cdot}1714} \cdot \frac{7{\cdot}00\times 980}{1{\cdot}2834}}$$

The values of n calculated by this formula are given in Table III and are plotted in fig. 4.

The results obtained with springs 2 and 6 were so similar to those obtained with 1 that it is unnecessary to give them here.

In order to study the behavior of a spring beyond the point where the length and tension were linearly related, it was necessary to modify the method of making the observations. The series with decreasing lengths was in all cases omitted, and several hours were left between successive sets of observations, so that the spring might recover as far as possible its original condition. Table IV and fig. 5 give the results for spring 3 obtained in this way.

TABLE IV. (Spring 3.)

T.	L.	L.	Observed n.	Calculated n.	Differences.
0	7·74	8	12·45	13·05	−0·60
10	8·62	9	16·89	17·09	−0·20
20	9·51	10	19·71	19·71	−0·00
30	10·41	11	21·62	21·61	+0·01
40	11·30	12	23·05	23·06	−0·01
50	12·20	13	24·21	24·22	−0·01
60	13·10	14	25·15	25·16	−0·01
70	14·00	15	25·96	25·95	+0·01
80	14·91	16	26·62	26·62	−0·00
90	15.84	17	27·16	27·19	−0·03
100	16·75	18	27·64	27·69	−0·05
110	17·69	19	28·07	28·13	−0·06
120	18·62	20	28·41	28·52	−0·11
130	19·59	21	28·73	28·87	−0·14
140	20·50	22	28·98	29·18	−0·20
150	21·45	23	39·19	29·46	−0·27
		24	29·30	29·71	−0·41

Data used in the calculations for spring 3:

$$\begin{array}{llll} \text{M} = & 2{\cdot}210 & m = & 11{\cdot}04 \\ \text{L}_1 = & 10 & n_1 = & 19{\cdot}71 \\ \text{L}_2 = & 16 & n_2 = & 26{\cdot}62 \\ y = & -0{\cdot}333 & x^1 = & -76{\cdot}55 \end{array}$$

In fig. 5 it is seen that the difference between the observed and calculated values of n becomes greater the further the length-tension curve departs from a straight line. This is just what would be expected, if springs obey the same law as vibra-

ting strings, in fact the equation requires that the percentage difference between the observed and calculated values of the frequency for a given length shall be twice the percentage difference between the observed and calculated values of the tension for the same length. If careful measurements are made on the plot, this will be found to be approximately true.

It is also seen in fig. 5 that n is apparently approaching a maximum value. This fact made it seem desirable to carry the curves considerably further beyond the point where the length and tension are linearly related. Since for this case only a

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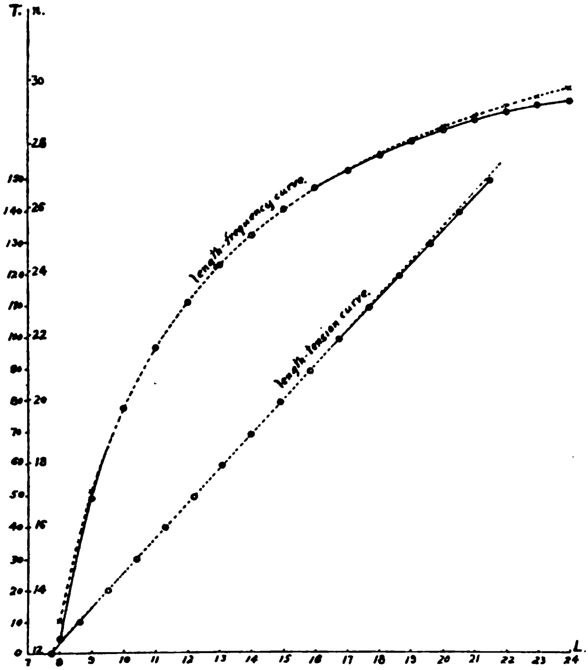

single set of observations could be made with one spring, on account of the permanent distortion produced, the most practicable method seemed to be to make two springs as nearly alike as possible. This was accomplished quite satisfactorily by cutting into two parts a very uniform spring and then adjusting the two parts until they had as nearly as possible the same mass, length and rate of extension.

Springs 4 and 5 were treated in this way, but the results were so similar that only those for 4 will be given. Table V shows how similar were the two parts into which spring 4 was made.

TABLE V.

T.	4a L.	4b.
0	12·18	12·18
20	13·63	13·63
40	15·10	15·08
60	16·56	16·55
80	18·03	18·03
100	19·53	19·51

Mass of $4a = 3·769$
" $4b = 3·783$

Springs $4a$ and $4b$ are certainly similar enough for the purposes of this investigation. The relation between the length and tension was determined with $4b$ and the relation between the length and frequency with $4a$. Table VI and fig. 6 give these results.

TABLE VI.

Spring 4b		Spring 4a			
T.	L.	L.	Observed n.	Calculated n.	Difference.
0	12·18	13	9·82	10·21	−0·39
20	13·63	14	12·56	12·72	−0·16
40	15·08	15	14·45	14·55	−1·10
60	16·55	16	15·92	15·96	−0·04
80	18·03	17	17·11	17·11	0·00
100	19·51	18	18·09	18·07	+0·02
120	21·00	19	18·91	18·88	+0·03
140	22·50	20	19·61	19·58	+0·03
160	24·00	22	20·75	20·72	+0·03
180	25·51	24	21·63	21·63	0·00
200	27·05	26	22·31	22·36	−0·05
220	28·66	28	22·85	22·98	−0·13
240	30·23	30	23·26	23·48	−0·22
260	32·03	32	23·58	23·92	−0·34
280	33·90	34	23·81	24·30	−0·49
300	35·90	36	23·88	24·63	−0·75
320	38·38	38	24·02	24·92	−0·90
340	40·83	40	24·02	25·18	−1·16
360	43·80	42	24·01	25·42	−1·41
380	46·60	44	23·88	25·63	−1·75
400	50·00	46	23·76	25·81	−2·05
		48	23·60	25·99	−2·39
		50	23·44	26·14	−2·70

Data used in the calculations for spring $4a$:

$M = 3·769$	$m = 13·50$
$L_1 = 17$	$n_1 = 17·11$
$L_2 = 24$	$n_2 = 21·63$
$y = -0·596$	$x^1 = -155·6$

The length-frequency curve for spring 4*a* differs from the others thus far studied in that the frequency has passed beyond the maximum point. If the frequency of the vibrations of the springs, when stretched beyond the elastic limit, obeys the same law as before, then along the flat maximum of the curve where

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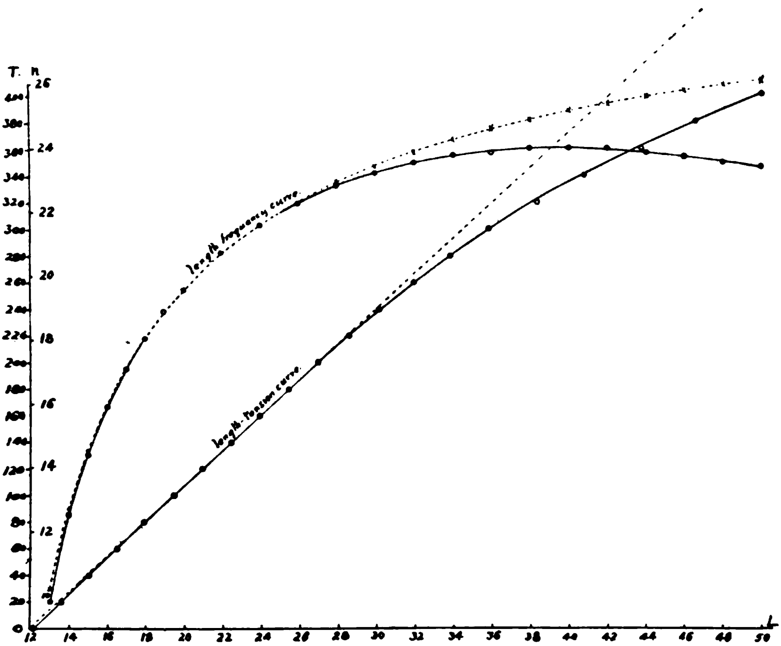

n is nearly constant, the ratio of T to L ought also to be nearly constant. An examination of fig. 6 gives the following values for n and $\frac{T}{L}$ for a few values of L along this part of the curve.

TABLE VII.

From Fig. 6.

L.	n.	$\frac{T}{L}$
34	23·81	8·26
36′	23·88	8·36
38	24·02	8·34
40	24·02	8·32
42	24·01	8·29
44	23·88	8·22

The above table makes it seem very probable that the frequency of vibration of a spring would be approximately constant through a long range of lengths, if it could be so made that $\frac{T}{L}$ would be constant along the linear part of the length-tension curve, or in other words if x in the equation $T = mL + x$ could be made zero. Spring 7 was made with this end in view. It differed from all the other springs made by having its turns

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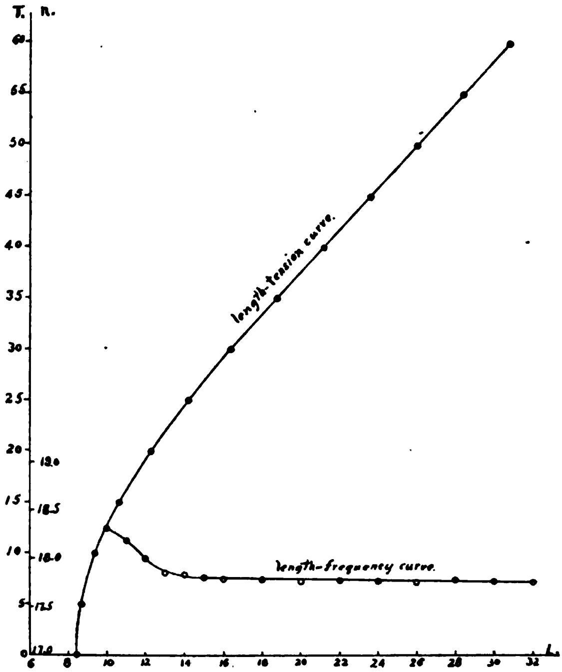

wound so tightly together that they did not become entirely separated until loaded with about 30 grams. The winding of this spring was more difficult than that of the others, and it was not nearly so uniform, but its frequency was very constant, differing only by one-twentieth of a vibration per second when its length was increased from 15 cm. to 32 cm.

The results for spring 7 are given in Table VIII, and the values are plotted in fig. 7.

TABLE VIII. (Spring 7.)

T.	L.	$\frac{T+x}{L.}$	L.	n.
0	8·43		10	9·32
5	8·69		11	9·18
10	9·37		12	9·01
15	10·63		13	8·86
20	12·31		14	8·84
25	14·22	1·990	15	8·81
30	16·42	2·028	16	8·79
35	18·80	2·037	18	8·78
40	21·23	2·040	20	8·77
45	23·66	2·041	22	8·78
50	26·09	2·043	24	8·77
55	28·51	2·045	26	8·76
60	30·90	2·048	28	8·78
			30	8·76
			32	8·76

In calculating the ratio of T to L, a small correction x equal to about one half the weight of the spring was added to T. As was expected, the frequency was very constant through the same range that $\frac{T+x}{L}$ was constant.

Sufficient evidence, I think, has been furnished to show that vibrating helical springs obey the same law as vibrating strings through a considerable range of length and tension. It would seem of interest now to examine the behavior of india-rubber cords under conditions as similar as possible to those experienced by the springs and to compare their behavior. For this pur-

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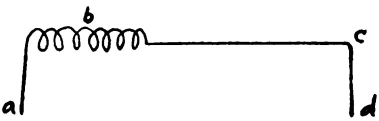

pose two samples of as pure rubber as could be obtained were used; one a rubber tube of about 4·68 mm. external and 3·06 mm. internal diameter, the other a rubber cord of square cross section, 1·16 mm. on a side.

The observations were taken in the same way as in the case of the springs, except that a slight modification had to be made in order to get electrical connection. In the case of the rubber tube a U-shaped piece of wire was hung on its center and held fast with rubber cement. The vibrations of the tube caused the two ends of the wire to dip into two mercury cups. In the

case of the rubber cord the contact was made by a very fine wire bent as shown in fig. 8.

The end *a* was firmly fastened. The point *c* was fastened with rubber cement to the rubber cord, the vibration of which caused the point *d* to dip into a mercury cup. The spring *b* was used to increase the flexibility of the wire until it had practically no period of vibration of its own. While there are some objections to this method of making the contact, the weight of the wire was so small and the adjustments made with such care, that the results are sufficiently satisfactory for com-

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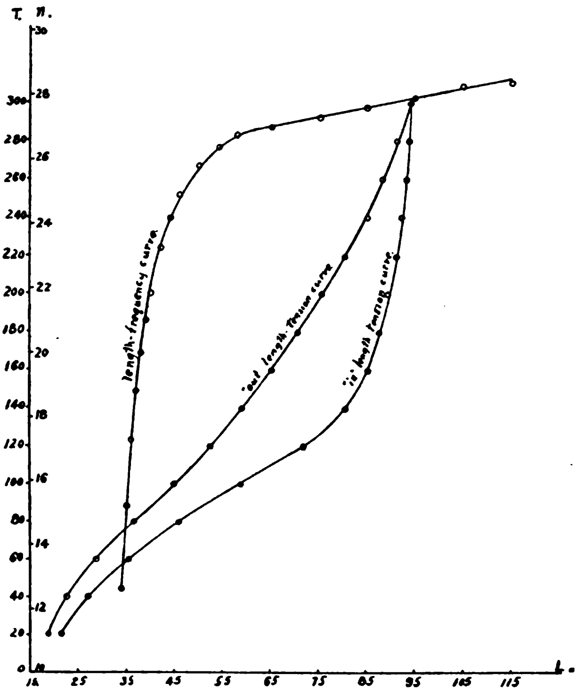

parison with those of the springs. In all cases with the rubber the successive observations were made as rapidly as possible, in order that time effects might be reduced to a minimum. Between the length-frequency observations and the length-tension observations time was allowed to elapse until the rubber practically recovered its original length.

The tube and the cord gave very similar results; those for the cord are given in Table IX and fig. 9.

TABLE IX. (Rubber cord.)

L.	n.	T.	Out L.	In L.
34	12·60	0	16·20	17·6
35	15·18	20	18·74	21·3
36	17·25	40	22·62	27·0
37	18·78	60	28·7	35·4
38	19·95	80	36·6	46.0
39	20·98	100	44·9	58·8
40	21·83	120	52·4	71·8
42	23·23	140	59·0	80·4
44	24·15	160	65·2	85·1
46	24·88	180	70·5	87·4
50	25·80	200	75·6	89·1
54	26·35	220	80·3	90·9
58	26·73	240	84·9	92·0
65	27·00	260	88·0	92·9
75	27·28	280	91·0	93·6
85	27·60	300	93·8	
95	27·90			
105	28·25			
115	28·38			

The similarity of the curves obtained with the rubber cord and those obtained with the springs is very noticeable. This is especially true for the first part of the length-tension curves in figs. 7 and 9, which would seem to indicate that the rubber is in a state of internal stress, even when there is no external tension, which was certainly true in the case of spring 7. Fig. 9 also shows what a very important effect the previous condition of the rubber has upon the relation between the length and tension. The condition of the rubber is also to a considerable degree dependent upon time and temperature, which explains why it is so difficult to make satisfactory measurements with it.

Although there are some irregularities in the curves given, especially those for the rubber, and for the springs when the tension was so small that the effect of the restraint of the ends was considerable, yet the following conclusions seem to be justified:

1. In the study of the transverse vibrations of helical springs and india-rubber cords one radical difference is noticed between them and ordinary strings, namely the fact that their length varies greatly with the tension instead of remaining very approximately constant.

2. While the frequency of the vibrations of the springs and rubber cord is expressed by the formula usually employed in the case of ordinary strings, yet the results obtained are very different on account of the great variations of the length with the tension.

3. The approximate constancy in pitch for a considerable change in length, which has been so often noticed with india-rubber cords, is also observed in a still more marked degree in the case of helical springs.

4. This approximate constancy of pitch for a considerable change in the length of both the rubber cords and the springs is due to the fact that during the change, the length and tension have remained nearly proportional.

In conclusion I desire to express my thanks to Professor A. W. Wright for suggesting the subject and furnishing the apparatus and assistance necessary in carrying on the investigation. I wish also to thank Mr. O. C. Lester for his assistance in performing the experimental work.

Sloane Physical Laboratory,
Yale University, May 1, 1904.

ART. XI.—*A new Type of Calcite from the Joplin Mining District;* by DOUGLAS B. STERRETT.

DURING the past spring an interesting type of calcite crystals has been added to those already produced by the prolific Joplin region. The crystals are all twins and show a uniformity of a development unusual for the species. They were obtained from a small cave discovered in the Maybell Mine at North Empire, Kansas. According to Mr. W. L. Bachtell, who has had charge of the removal of the crystals, the cave was opened at a depth of 135 feet while blasting in the chert. It was 50 feet long, 4 to 8 feet high and 6 to 12 feet wide. Specimens were sent by Mr. Bachtell to Prof. E. S. Dana at New Haven, and it is at his suggestion that this brief study of their forms and development has been undertaken. These specimens, with others loaned to the writer by Mr. George L. English of New York, and one from the Brush collection, were used in the preparation of this article. Mr. English described this new occurrence in a lecture before the New York Mineralogical club on March 15th. Since his lecture was not published, it has been deemed advisable to give a brief description of the occurrence and of some characteristic specimens.

Most of the crystals are very large. Mr. English states that according to the information that has come to him, probably less than two hundred were obtained from the cave, and only some dozen or so were of a size suitable for cabinet drawer specimens. One of the larger crystals, now in the Yale College collection, measures $39{\cdot}5^{cm}$ along the reëntrant angle, 19^{cm} in thickness and 30^{cm} high, according to the orientation chosen in fig. 1. This crystal weighs 62 pounds and is very well developed for one of such size. Probably the smallest is the one shown in fig. 2, which is only $4{\cdot}7^{cm}$ in greatest length. One remarkable feature which most of these crystals possess is a delicate amethystine or lilac color, much resembling that of the pale-colored kunzite. The color is not uniformly distributed through the crystals, but is confined chiefly to the outer parts and appears to lie in a plane parallel to the crystal faces, especially the *e* face. Owing to their form and great beauty of color, they are called the "amethystine twin calcites."

The crystals are twinned on the *e* face ($01\bar{1}2$), according to a very common law for calcite. In representing them, drawings were made with the twinning plane vertical (as in figs 1 and 2), also with the lower crystal in normal position for a positive form while the upper negative crystal was tilted back into twin position (as in figs. 3, 4 and 5). Measurements were made

on some of the smaller crystals, the quality of which allowed very satisfactory determinations of the following forms:

r $(10\bar{1}1)$	f $(20\bar{2}1)$	t $(21\bar{3}4)$
M $(40\bar{4}1)$	l $(40\bar{4}5)$	C $(61\bar{7}8)$
m $(10\bar{1}0)$	e $(10\bar{1}2)$	

The l face on most of the crystals is so etched as to be difficult to measure. On one small crystal, however, it gave fairly good reflections and an average value was obtained of $m \wedge l =$ 51° 56′; theory 51° 43′. The C faces appeared to be only vicinal growths on r, but when measured gave good reflections and an average value of $C \wedge r = 8°\ 44\frac{1}{2}'$; theory 8° 46′.

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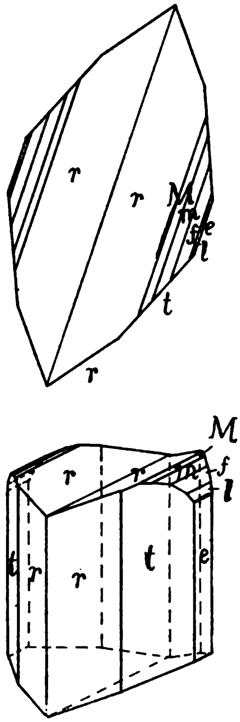

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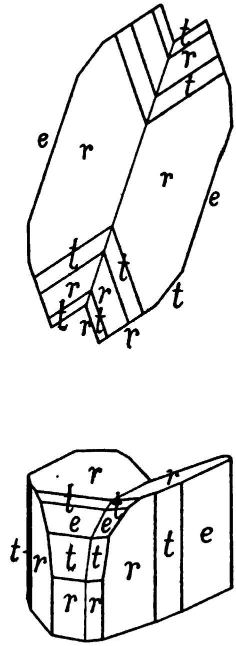

Fig. 1 represents a quite symmetrically developed crystal belonging to the Yale College collection. It was found that a drawing, made in clinographic projection with the twinning plane vertical, gave little idea as to the length along the twinning plane; so orthographic projections were also made to accompany figs. 1 and 2. Fig. 2 shows the development of

a small crystal loaned by Mr. English. It might be considered as made up of two separate individuals grown together in twin position. On each the zone *r*, *t* and *e* appears three times. There was a very small development of the faces of the zone *r*, *M*, *m* — — — and *e* in their proper positions, though these are not shown in the figure. Fig. 3 represents an ideal

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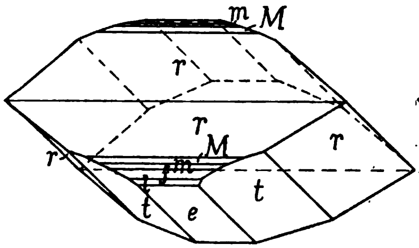

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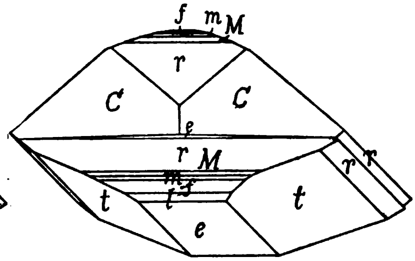

development of a crystal which is given in its natural distortion in fig. 4. The *C* faces were not drawn in fig. 3, since they occur only on one of the twins. As shown in fig. 4, they form an intersection with the twinning plane *e*, which extends above the line of intersection of the twin crystals. This crystal is apparently terminated below by natural *r* faces parallel to those above and forming an obtuse angle. In most of the crystals a natural termination fails, and its place is occupied by cleavage planes developed when the crystals were detached from the rock. On some crystals the *e* face is wanting, in

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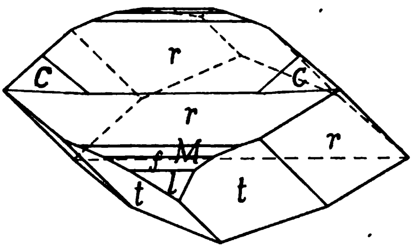

which case *l* has a larger development, as shown in fig. 5. This represents a large specimen in the Brush collection on which the *C* faces appear again only on one of the crystals. In this case they form no intersection with the twinning plane, as in fig. 4, but together with *r* of the upper crystal overlap the lower one, meeting the *r* of the latter beyond the twinning

plane. The occurrence of *C* on only one individual of a twin was observed on four specimens, while on the large crystal described above, *C* occurred on both.

The crystals show a tendency toward a prismatic development parallel to the *e* faces. This was further marked by pits or negative crystals of prismatic form observed on the *e* faces of one crystal. The faces of the negative crystal were parallel to the unit rhombohedrons, and therefore rhombohedral themselves. One crystal, probably from another opening in the same mine, showed the same method of twinning, though this fact was nearly concealed by the development of very large *v* faces nearly covering the reëntrant angle of the twins.

The development of a twin crystal similar to those described above was observed on a single specimen of golden calcite from the Joplin region about two years ago by Mr. English.

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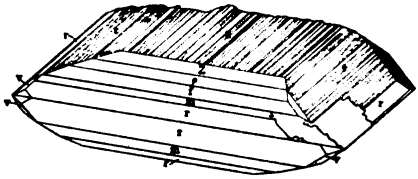


At his request, a drawing of it was prepared by Mr. H. P. Whitlock; Mr. English has kindly allowed a copy of the figure to be inserted here for comparison. The letters represent forms found in Dana's System of Mineralogy. Whether other crystals were found and what was the exact locality for this could not be learned.

In conclusion, acknowledgment is made to Mr. English for generously supplying material for examination, and to Prof. E. S. Dana and Dr. W. E. Ford for assistance in the preparation of this paper.

Sheffield Laboratory of Mineralogy,
Yale University, New Haven.

ART. XII.—*Radium and the Electron Theory;* by JOHN TROWBRIDGE and WILLIAM ROLLINS.

THE mechanism of electric conduction through metals continues to be one of the greatest mysteries of electricity; and there is no plausible explanation of it unless we accept the theory of electrons. This theory, as is well known, supposes the existence of small bodies called electrons, which move between the molecules of the metals during the passage of an electric current. It has been much developed by Drude.*

The theory seems to bring the electrical conduction in metals into close touch with conduction in gases; for in both cases we suppose a movement of small particles. These particles have a greater free-path in rarified gases than they have between the molecules of a metal, and their action is much modified by the X-rays. This modification is usually attributed to a species of ionization due to a physical connection between the energy emitted by the X-rays and the transformation of energy witnessed in the rarified gas. A Geissler tube, for instance, which will not permit the passage of an electric current, when the degree of exhaustion is beyond the point of breaking down with the electromotive force employed, is made conducting when the X-rays fall upon it.

We mention this fact in order to give a significance to our experiments with radium. This remarkable substance, also, in common with the X-rays can affect by what we call ionization, the conduction of electricity through gases. The X-rays and certain emanations of radium can also pass through thin sheets of metal, especially sheets of aluminium. We are, therefore, for the first time in the history of electricity, in a condition to test the question, whether radiant energy exhibiting light and passing through a metal can affect the passage of a current of electricity.

In this connection one is immediately reminded of Faraday's attempt to discover whether ordinary light is modified in passing through an electrolyte which is submitted to the action of a current of electricity. He thought that there might be a state of tension which could be detected by polarized light; and he therefore passed a beam of polarized light in the direction of the current and also at right angles to this direction. The result of the experiment was negative; absolutely no effect was observed. Faraday's custom of publishing both positive and negative results has its advantages, especially in the early days of a science; and particularly when it shows us

* Ann. der Physik., No. 1, 1900.

the working of a great mind groping in a region not yet submitted to calculation. Lesser minds must, however, use caution in publishing negative results; for due regard must be had for brevity of publication and the limits of experimentation.

Can we not, however, imagine Faraday continuing his efforts to discover some connection between the passage of light through an electrolyte or a conductor and the passage of a current of electricity, if he could penetrate such a conductor by light. In other words, might he not have been tempted, if he had had command of the X-rays or radium, to discover some action of the energy emitted by the new and wonderful manifestations on a current? Apart, however, from such a view of the working of the great physicist's mind, can we not get a foothold in mounting to the heights of the electron theory by endeavoring to show that the X-rays or the emanations from radium do or do not have a discoverable action upon the passage of an electric current, through aluminium for instance?

It must be premised that no mass is ascribed to the electron. Its supposable inertia is due to self-induction, and perhaps it should not be called a body. On this conception it does not seem probable that particles shot off from radium, or ions resulting from the radiation of X-rays, could influence such immaterial bodies. Nevertheless our view of the electron theory might be influenced by proceeding to an actual test, and by looking at the results and limitations of possible experiments. We therefore experimented as follows:

A meter of aluminium wire No. 24 was wound in five turns around a thick sheet of lead which was eight centimeters in length and one centimeter in width. The wire was wound around the longest dimension of this shuttle-like piece of metal, and was insulated from it by thin sheets of vulcanite. The electric current, therefore, passed in one direction along the upper layer of the wire, and in the opposite direction along the lower layer. The lead, intervening between the upper and lower layer, could serve to confine the radiations from suitably placed radium either to the upper or the lower layer of wire. The lead shuttle with its layer of wire was enclosed in a lead cylinder and a specimen of pure radium bromide was enclosed at one end of the layers of wire so that its emanations could sweep along the upper or the lower layer of this wire. A lead diaphragm could be used to shut off the entire effects of the radium from the wires.

The wire was made one branch of a Carey-Foster bridge; a suitable key made it possible to reverse the current through the aluminium wire, and after adjustment the wire was exposed to the radiations from the aluminium under the varying conditions of reversals of current; radiations confined to the lower layer

and afterwards to the upper layer. The bridge was competent to detect a change in resistance of one hundredth-thousandth of an ohm. On account of the difficulty of distinguishing between a heating effect and what may be called an electrodynamic effect, the observations occupied a comparatively short interval of time. No instantaneous effect was observed: a very slight creeping deviation of the galvanometer mirror came after a considerable interval of time, which might have been due to change of temperature. It could not be ascribed with reason to the presence of the radium.

The light from the radium could be seen through a slab of iron an inch thick; yet this manifestation of energy passed through the aluminium without any apparent effect upon the mechanism of the electric current. Should we reason, therefore, from this negative experiment that the theory of the immaterial electron is supported, or that a theory of dissociative effect on gases between each molecule of the metallic conductor under the effect of a current is also negatived: for the radium emanations, like the X-rays, can produce this dissociative effect in the passage of electricity through gases?

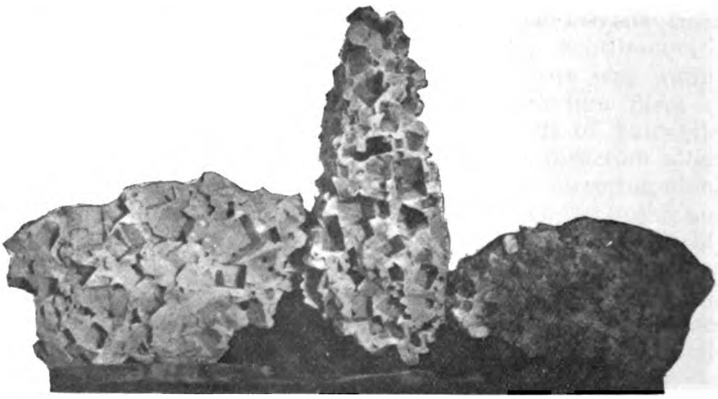
Mr. McKay, graduate student working in this laboratory, has endeavored to detect the effect of the X-rays in changing the apparent resistance of thin films of metals. The effect, if it exists, is extremely small. He, however, is still continuing his work upon this subject.

Jefferson Physical Laboratory,
Harvard University.

ART. XIII.—*Pseudomorphs and Crystal Cavities;* by J. P. ROWE.

SOME of the finest pseudomorphs and crystal cavities the writer has ever seen came to his notice recently from specimens collected near Shoshone, Idaho. The material was collected and sent to the University of Montana by Rev. T. L. Lewis. The natural mineral is pyrite, imbedded crystals; the pseudomorph, limonite; and the matrix, a fairly pure, light colored, quartzite.

Specimens were found showing the unaltered pyrite cubes below imbedded in pure homogeneous quartzite, the pseudomorphs of limonite above in the same material, and still higher the beautiful and perfect cavities, where the pseudomorphs had been dissolved out by the action, probably, of meteoric water. Almost all of these cavities show the delicate striations of the pyrite cubes. The matrix is literally filled with these cavities and presents a regular honeycombed appearance. The size of the cavities range from ·15 of a centimeter in diameter to 2·5 centimeters. However, but few if any of the cavities are perfect cubes. One of the most interesting things about these specimens is, that the distance from the pyrite crystals to the crystal cavities, i. e. including the pseudomorph limonite, in many instances, is not more than five centimeters. In fact, in many cases the pseudomorphs are not more than 1·5 to 2 centimeters from the pyrite crystals.



Taking it all in all the specimens are very beautiful. They show the transition of the pyrite to the limonite as do but very few specimens. They also show that limonite is easily soluble in certain kinds of water. They still show how these cavities might be refilled with quartz or calcite or some other mineral from solution and again give false forms, not true pseudomorphs as in the first instance, but so to all appearances.

University of Montana, Missoula, April 29, 1904.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Emanium.*—F. GIESEL has obtained from pitchblende an earth consisting chiefly of lanthanum which shows strong radioactive properties. He finds that the behavior of the material is different from that of radium, and believes that he has obtained a new element which he calls emanium and which he hopes to separate from lanthanum. The striking characteristic of this material appears to be an emanation given off by it. When air is blown through a flask containing preparations of the substance enclosed in paper capsules, and the air issues from a tube against a blende screen, a brilliant illumination is produced, and scintillations can be observed, even with the naked eye. The "sparks" are more distinct and larger than those produced by radium or polonium, and hence the material is more effective than these for use in the spinthariscope.—*Berichte*, xxxvii, 1696. H. L. W.

2. *Radio-activity and Matter.*—This topic has been recently discussed by Professor WINKLER, who is perhaps the most prominent inorganic chemist in Germany. The great importance of the recent discoveries connected with radio-active substances is admitted, but the author doubts that the existence of new elements in this connection has been satisfactorily demonstrated. He is inclined to consider radio-activity as a purely physical process, which, like magnetism, may act upon matter without affecting its chemical nature. He points out that radium, which was discovered nearly six years ago, is but slightly known in its chemical relations, and that nothing can be stated about it in this respect, except that it is remarkably similar to barium, but has a higher atomic weight. The further chemical study of radium and other radio-active substances is advocated, and the suggestion is made that material for such work may be obtained from certain rocks, especially granites, occurring in Germany, which are known to contain uranium minerals.—*Berichte*, xxxvii, 1655.

H. L. W.

3. *Detection of Chlorides in the Presence of Bromides.*—Many methods have been proposed for the detection of small quantities of chlorides in the presence of bromides in qualitative analysis, but most of them present difficulties in the hands of students. CHAPMAN JONES has recently proposed for this purpose the treatment of the mixed silver salts with a cold saturated solution of ammonium bicarbonate. The reagent is poured over the precipitate on the filter paper and is acidified with nitric acid after it has run through. When the reagent is allowed to remain in contact with silver salts for a few minutes with occasional agitation, the precipitate produced by acidifying will be greater in the case of the chloride, while the treatment of the bromide may be continued sometimes for half an hour without giving a positive result. In a case of doubt, the acidified liquid may be

divided into two parts; to one is added a slight excess of ammonium bicarbonate solution, and to the other an equal quantity of water. If the turbidity is due to silver chloride, it will dissolve in a few moments, but if it is due to the bromide it will remain undissolved for several minutes, if not for an hour or more.—*Chem. News*, lxxxix, 129. H. L. W.

4. *Solubility of Silicon in Zinc and Lead.*—MOISSAN and SIEMENS have found that silicon dissolves in zinc at a much lower temperature than in lead. In zinc the solubility begins at 550°, and amounts to 1·6 per cent at 850°. In the case of lead the solubility begins at 1100°, and at 1400° it amounts to only 0·15 per cent, while at the boiling-point of lead, about 1550°, it amounts to only about 0·79 per cent.—*Berichte*, xxxvii, 2086. H. L. W.

5. *Analytical Chemistry, Volume II, Quantitative Analysis;* by F. P. TREADWELL: translated from the Second German Edition by William F. Hall. 8vo, pp. 654, with 96 figures. New York, 1904. (John Wiley & Sons, price $4.00.)—A satisfactory text-book for students in quantitative analysis has long been needed, and it appears that the work under consideration will fill this want admirably, and that it will be a most useful book of reference for practical analysts. The most modern and satisfactory methods of analysis are ably presented, and the book is not encumbered with antiquated and superseded processes. The best electrolytic methods are included, as well as methods of fire assaying for gold and silver ores, while separate parts of the book give excellent treatises on volumetric analysis and gas analysis. The modern aspect of the work will be evident when it is stated that the use of the Gooch crucible is strongly advocated (although the details given for its use appear to be unduly complicated, probably from lack of experience with the proper kind of asbestos), and also from the fact that many other American methods, such as those of Gooch and his pupils, Hillebrand, and others, are given. This attitude towards American improvements is in agreeable contrast with the usual conservatism displayed in this respect by European works on analytical chemistry. The translator has also helped in this direction by making certain additions and changes with the object of rendering the book more useful to English-speaking students. H. L. W.

6. *Laboratory Exercises in Physical Chemistry;* by F. H. GETMAN. 12mo, pp. 241. New York, 1904. (Wiley & Sons.)—There has been previously no suitable laboratory text-book in physico-chemical measurements which could be used by the average student, and the present volume has been written to meet this requirement. The customary measurements in physical chemistry are well described in detail, with the apparatus required. Usually but one method is given for each measurement. We notice that in describing the boiling-point apparatus only the Jones form is described, while no mention is made of the Beckmann form. There is a set of convenient tables added at the end of the book. H. W. F.

7. *Chemie der Eiweisskoerper;* von Dr. OTTO COHNHEIM; Zweite Auflage, Braunschweig, 1904. (Fr. Vieweg und Sohn.)—The publication, in 1900, of a monograph of three hundred pages devoted to the literature of the chemistry of the proteids emphasized the importance which the study of this unique and significant group of compounds has assumed in biological chemistry. The appearance, scarcely four years later, of a new edition of Cohnheim's book, not merely revised but entirely rewritten, gives evidence of the marked progress which has attended recent investigation in this field of study. It is no exaggeration to say that during this interval our ideas regarding the structure of the albuminous bodies have been radically altered in various ways. Investigators and students will therefore welcome the new edition as a useful aid. The judgment which the author has displayed in dismissing with brief reference those theories and facts which no longer possess more than historical interest, and in directing attention to the permanent acquisitions to our knowledge, deserves commendation. From this it will be understood that Cohnheim's book is something more than a mere compilation; indeed, critique is displayed in every chapter. The more important advances appear in the review of the cleavage products of the proteids and in a discussion of their chemical constitution. The almost unavoidable occasional omissions of reference to important papers are apparently few; and the completeness thus attained gives an added value to the work. L. B. M.

8. *Vapor pressure of Mercury at ordinary Temperatures.*—EDWARD W. MORLEY gives a résumé of the work of previous observers of this pressure. The work of Regnault must be dismissed from consideration, for his experimental means were not sufficiently delicate and precise. Hagen's measurement also must be disregarded because his interpolation formula is inconsistent with what we know of the behaviour of saturated vapors. The experiments of Hertz, of Ramsay and Young, agree with those obtained by Morley, while those obtained by Van der Plaats differ widely. A table of vapor pressures is appended to the article.—*Phil. Mag.*, June, 1904, pp. 662–667. J. T.

9. *The Penetrating Rays of Radium.*—The γ-rays of radium have been likened to the X-rays on account of their penetrating power and their not being deflected by a magnet. E. PASCHEN has made a study of this penetrating power. The rays have a very different absorption-coefficient from the X-rays. The author points out incidentally, that the commonly based method of ionizing the air is not suitable for determining the absorption. The rays lose their power of ionizing the air in passing through layers of lead. The γ-rays appear to have a velocity approximating to that of light and they possess great interest; for we apparently have in their case electrical quantities moving with the velocity of light.—*Ann. der Phys.*, No. 6, 1904, pp. 164–179. J. T.

10. *Use of the Thread Galvanometer.*—W. EINTHOVEN described in Ann. der Phys., p. 1059, 1903, a galvanometer which consisted in the main of a silvered quartz fiber stretched between the poles of a magnet. He now explains some further peculiarities and uses of the instrument. He has repeated the Curies' measurement of radio-activity of various substances by the use of his instrument instead of the electrometer and finds it more suitable for the purpose. The currents measured were of the order 5×10^{-11} amp. He also measured insulation resistances of the order of a million megohms. A quantity of electricity 5×10^{-12} ampere-seconds can be detected. In general the instrument is suitable for many uses to which the electrometer has been put; and it is especially useful to detect and measure feeble sounds or telephone currents.—*Ann. der Phys.*, No. 6, pp. 182–192, 1904. J. T.

11. *The Hot Oxide Coherer.*—MAX HORNEMANN states that he described this coherer in 1902, while Branly's paper on the same subject appeared in 1904. Heated and then cooled particles of iron possess, on account of the layer of oxide, a peculiar sensitiveness to electrical waves. The author had shown this property of cold oxide layers and lately has investigated the influence of heat on the sensitiveness of such layers. He found that hot layers of the oxide, if they are of the same metal throughout, do not possess any marked superiority over the cold particles; but if he used layers of different metals, for instance, lead with an oxidized (not noble) metal, he obtained a much greater sensitiveness. With a hot lead copper contact he could detect the purring of a little induction coil at a distance of 12 meters and through intervening walls.

Hornemann has studied this effect of the heated oxide layer by means of a galvanometer and suitable electric circuits; but is not certain of the reason for this peculiar action of heat on the coherer. The property seems to be an important one with reference to wireless telegraphy.—*Ann der Phys.*, No. 6, pp. 129–138, 1904. J. T.

12. *X-Rays and N-Rays;* by R. BLONDLOT.—* * * * The consideration of the kind of symmetry belonging to a Crookes' tube suggested to me the possibility that the rays emitted by it might be polarized on their emission. I proved, in fact, that a small electric spark, subjected to their action, increased in brilliancy when the discharge was parallel to the axis of a Crookes' tube, and that this reinforcement did not take place when normal to the axis. This indicated that the rays emitted had indeed the want of symmetry characteristic of polarization. This point established, I demonstrated at once the existence of rotatory polarization: quartz, sugar, etc., served to rotate the plane of polarization of the radiations produced by a Crookes' tube. I then conceived the idea of trying the rotation by a series of mica plates, after the manner of Reusch: this rotation in fact took place. I was thus led to examine the effect of a single lamina

of mica: this gave elliptic polarization. But the facts stated proved the existence of double refraction and made *à fortiori* simple refraction highly probable. I proved then further that the radiations which I had studied were really deviated by a quartz prism and could be concentrated by a lens; it was also shown that they were reflected by a plate of smooth glass and diffused by an unpolished glass surface.

The facts stated indicate that the rays under examination were not Roentgen rays or X-rays, which suffer neither reflection nor refraction, but a new kind of rays traversing aluminium, wood; black paper, etc., polarized rectilineally on emission, susceptible of rotatory and elliptical polarization, and reflected or diffused, but producing neither fluorescence nor photographic action. To this kind of radiation I gave the name of *N-rays*. It is to the N-rays, in fact, that the phenomena of polarization pertain which I had observed and at first attributed to X-rays. If we analyze by a quartz prism the complex of rays emitted by a Crookes' tube, it is found that the X-rays are not deviated while the N-rays are deflected toward the base of the prism. It is easy then to prove that the N-rays alone act on a small spark while the X-rays seem to have no action on it. I have thus established the polarization of the N-rays and not that of the X-rays; also the velocity of propagation, which I have measured by a method published in these *Archives*, belongs not to the X-rays but to the N-rays. The confusion was unavoidable until the existence of the new radiations was recognized.

A further study of the N-rays has enabled me to prove that any source of light of very small intensity may be employed to show their existence, as a small gas flame, a platinum wire at a red heat, a phosphorescent screen. All of these sources of light have their brilliancy increased by the action of N-rays. A Crookes' tube is not the only source of N-rays; they are emitted also by an electric arc, a Nernst lamp, an Aner burner, and most of all by the sun.

The reflection and refraction of the N-rays follow the same laws as those of light; in particular the law of Descarlis has been verified with a high degree of precision in the experiments made with prisms and lens (of aluminium). In the emission from a Nernst lamp I have proved the existence of a large number of radiations of different indices comprised between the values 1·04 and 1·85. I have isolated the different pencils by the aid of an aluminium prism, I have measured their wave-length by the aid of *reseaux* traced on glass by the classic method, and the method, based upon the use of Newton's rings, has given results agreeing with the preceding. The wave-lengths are comprised between 0^{μ}·0081 for the index 1·04 and 0^{μ}·0176 for the index 1·85.

It follows from what has preceded that the N-rays are completely analogous to light, from which they differ only in the lengths of the waves, which are much shorter. Now light, ultra-

violet radiation, infra-red radiation and the Hertz radiations, which according to the electro-magnetic theory of light are an extension of light radiations, are propagated with one and the same velocity. In other words, there is a velocity of propagation common to all kinds of radiation and independent of the wave-length. It is thus, as it were, certain *à priori* that the N-rays, all of whose properties approach those of light, and which are surely a variety of it, should have the same velocity. This is precisely what the experiments already described in these *Archives* show. This verification of a fact reasonably sure in advance seems to me not without interest; it confirms the complete unity of character of what we now call the N-rays.—*Archives des Sciences, phys. et nat.*, Geneva, xvii, May, 1904.

13. *Lehrbuch der Physik;* von O. D. CHWOLSON; übersetzt von H. PFLAUM. Bd II., pp. xxii + 1056. (Braunschweig: F. Vieweg und Sohn.)—The second volume of this work presents the same admirable qualities as the first volume, which has been previously reviewed in this Journal.* It comprises the subjects of sound and light and is an exhaustive presentation of the phenomena and, so far as is possible with elementary mathematical methods, of the theory also. The descriptive portions are exceedingly clear, the perspective good, and the arrangement so logical that, notwithstanding the great number of details presented, the treatment of the various subjects has a unity somewhat rare in works of this character. A very useful feature is the list, at the end of each chapter, of important original papers bearing upon the subjects treated in the chapter. H. A. B.

14. *Applications of the Kinetic Theory;* by W. P. BOYNTON. pp. x + 288. New York. (The Macmillan Co.)—This is a well-arranged collection of the principal theorems and applications of the Kinetic Theory, in which physical ideas are not lost sight of by over emphasis upon the mathematical details. The treatment is, in the main, elementary and the methods employed are those of the founders of the theory, rather than the more general ones developed by Boltzmann and other recent writers upon the subject. The author has succeeded in giving a fairly complete account of the subject without assuming a very extensive acquaintance, on the part of his readers, with mathematics and mechanics; he has avoided the discussion of logical subtleties and delicate questions of rigor which occupy much attention at present, but which the beginner can well afford to do without. The successive chapters deal with ideal gases, gases whose molecules have dimensions, diffusion and viscosity, change of state, the equation of van der Waals, vaporization, liquids, solution, dissociation and condensation, and a summary containing numerical applications, etc. A knowledge of empirical thermodynamics is not assumed, but is given in the text when it is necessary for a comparison between the results of the theory and those of experiment. H. A. B.

* See volume xv, p. 82, Jan. 1903.

15. *Entropy; or Thermodynamics from an Engineer's Standpoint, and the Reversibility of Thermodynamics;* by JAMES SWINBURNE. Westminster. Pp. x + 137. (Archibald Constable and Co.)—This book is the outcome of discussion carried on by the author and others during the latter part of 1903 in the columns of the London Engineering. This discussion has been of great value in calling renewed attention to the importance and difficulties of the thermodynamics of irreversible changes. Mr. Swinburne's contribution cannot, however, be said to be thoroughly satisfactory, unless considered alone for its suggestiveness, and for its rather amusing polemical rigor. In order to put more emphasis on irreversible changes, which are the only real changes occurring in nature, and in order to gain a more physical notion of entropy, he proposes a new order of development of the principles of the science. That these praiseworthy objects have been successfully attained seems doubtful, though the suggestiveness arising from the change in viewpoint cannot fail to be of value to the thoughful reader. The accepted or orthodox (as Mr. Swinburne for controversial purposes prefers to call it) presentation of the science starts with those laws of the transformation of energy which are known as the two laws of thermodynamics; then comes the consideration of the reversible process and cycle from which, by application of the second law, we get the idea of entropy and its conservation; then passing to irreversible or actual processes, we arrive at the notion of the waste in such processes and the growth of entropy. The presentation proposed in this book starts, as does the ordinary treatment, with the same two laws of energy transformation, though Mr. Swinburne unnecessarily mars the presentation by inserting a wholly gratuitous third law, i. e. that a frictionless mechanism is unrealisable; then follows the consideration of the irreversible or actual process, the waste incurred in such processes, the definition of entropy as the measure of the waste, and the doctrine of the growth of entropy; then taking up the ideal reversible cycle, the working definition or mathematical expression for the entropy (or rather for its minimum value) is obtained. Now, aside from the pugnacious manner in which it is presented, and leaving out the unessential and unfortunate "third" law, there can be no valid objection to looking at thermodynamics in this way if one so wishes; in fact, the reviewer feels under a great personal obligation to Mr. Swinburne for proposing this very suggestive alternative viewpoint. When, however, he comes, in the third and fourth chapters, to consider in detail certain irreversible changes, one cannot criticise the author so favorably. There is a lamentable confusion in the matter of the "heat of a body," and, in particular, the restriction of the temperature, in the expression for entropy to the temperature of the envelope, cannot be admitted. A criticism of less moment is that Mr. Swinburne's contention that the state of development of a science is a function of the names it possesses for its units, and that therefore thermodynamics will continue in

a backward condition until his proposal of the "claus" for the unit of entropy is adopted, appears more amusing than convincing.

In conclusion, it may be said that the wish expressed in the last paragraph of the appendix—"that the somewhat novel way of arranging and treating the subject-matter of the groundwork of thermodynamics may meet with the approval of those who specially deal with that science"—will perhaps see a fair measure of fulfillment. The remainder of the subject matter illustrates, in a manner unfortunately not rare, the statement made at the end of the fourth chapter, that thermodynamics "is perhaps the most slippery branch of science there is." L. P. W.

16. *Electricity and Matter;* by J. J. THOMSON, 162 pp. New York, 1904 (Charles Scribner's Sons).—This volume gives in full the six lectures delivered by Professor Thomson at Yale University, on the Silliman foundation, in May, 1903. Those who were so fortunate as to hear this most interesting and suggestive discussion of the nature of electricity and constitution of matter, by one whose own contributions have been of the first importance, will be glad to have the lectures preserved for them in permanent form. The volume also serves the more important end of enabling the gifted lecturer to reach a much larger audience; this, indeed, should include all those who are interested in the progress of science and who, at the same time, have some basis of physical knowledge to make their reading intelligent.

17. *Étude sur les Resonances dans les Réseaux de distribution par Courants alternatifs;* par G. CHEVRIER. 76 pp. Paris, 1904 (édité par l'Éclairage Electrique). — This is a systematic and homogeneous presentation of a subject, the various aspects of which have been discussed by numerous authors from different points of view. The theory of oscillatory movements in general is given first, followed by a presentation of the theory specialized for the case of circuits with capacity and self-induction. The third part gives the application of the results obtained to the condition of the practical current.

18. *Elektrische Fernphotographie und Ähnliches;* von Dr. ARTHUR KORN. 66 pp. Leipzig, 1904 (S. Hirzel).—The author here reproduces three memoirs, recently published in the *Physikalische Zeitschrift,* giving an exact description of his methods and apparatus; a historical introduction is added. Those who have not kept up with the progress in this interesting line of experiment will be surprised to see what can now be accomplished.

19. *The Telescope;* by THOMAS NOLAN. Second edition, revised and enlarged, 128 pp., 12mo. New York, 1904 (D. Van Nostrand Company).—To the matter contained in the first edition of this little book, there has been added a new chapter describing the advances made since 1880 and, following this, a bibliography of the important literature on the telescope. The author has succeeded in setting before the reader a large amount of interesting information simply presented and in a very small space.

20. *Scientia, Phys. Mathématique*, No. 23. Paris, 1904 (C. Naud).—This recent number of the valuable series of scientific memoirs now being published in Paris is by H. Poincaré, and is devoted to the subject of the theory of Maxwell and the oscillations of Hertz, with their application to wireless telegraphy. It is an excellent presentation of a very interesting subject.

II. Geology and Natural History.

1. *Glacial Conglomerate, Transvaal, South Africa.*—A proof sheet recently received from the Geological Society of South Africa announces the discovery by E. T. Mellor of extensive glaciated surfaces and deposits 25 miles east of Pretoria. The deposits represent the lower portion of the Highveld Formation, lying immediately below the Coal Measures and "consist of irregularly alternating, usually more or less lenticular deposits of conglomerates, sandstones, and shales. The conglomerates have all the characters usual to ground-moraines. They contain an assemblage of bowlders very miscellaneous in composition and size, embedded in a clayey, or more frequently sandy, matrix full of smaller angular rock fragments. Bedding planes are rarely met with. The bowlders are polished, facetted, and in the case of those composed of material sufficiently fine in grain, frequently striated. The sandstones are also very irregular in thickness, often massive and without traces of bedding; they are white, yellow, or cream-colored, and though often fine in texture, very rough to the touch. The shales are white or cream-colored. They frequently show fine lamination, very regular over short distances, but not persistent over any considerable area. More frequently they partake of the nature of mudstones. These shales are more abundantly developed near the upper portion of the glacial series."

"The glacial deposits were laid down upon a land surface of considerable variety, many features of which reappear with slight modification in the landscape of to-day." Wherever the glaciated deposits are removed by erosion, glaciated surfaces are of frequent occurrence. The striae and bowlders alike abundantly prove that the ice movement was N.N.W. to S.S.E. This direction is in accord with the observations of Rogers and Schwartz at Prieska, Cape Colony (Ann. Report Geol. Com. 1899) and of Schenck near the junction of the Orange and Vaal Rivers (Ueber Glacialerscheinungen in Süd Afrika), but not with the observations of Molengraaff in the Vryheid district (Trans. Geol. Soc. of S. A., IV, pt. V, 1898). The wide extent of the glacial deposits, their presence at various elevations, and the parallelism and constancy of direction of the striae in the Transvaal locality indicates a considerable thickness for the ice sheet.

2. *Wisconsin Geological and Natural History Survey.* E. A. Birge, Director.—Two bulletins of the Wisconsin Survey have recently been published.

Bulletin No. XI.—Preliminary Report on the Soils and Agricultural Conditions of North Central Wisconsin; by Samuel

WEIDMAN. 64 pp., 10 pls., including soil map.—The different classes of glacial drift constitute the principal part of the surface outcrops of Central Wisconsin and these formations are described in detail as to character, water content, etc. Climatic conditions are discussed in Chapter III, (pp. 49–64).

BULLETIN XII.—The Plankton of Lake Winnebago and Green Lake; by G. DWIGHT MARSH. 89 pp., 22 pls.—A comparative study of the Plankton of two lakes of different types has been carried on for a considerable time and many facts regarding the annual and geographical distribution of the animals and plants have been secured. The principles controlling distribution are also discussed.

3. *Geological Survey of Ohio.* EDWARD ORTON, JR., State Geologist. Fourth Series, Bulletin 1. The Occurrence and Exploitation of Petroleum and Natural Gas in Ohio; by J. A. BOWNOCKER. 320 pp., 6 pls., 10 maps.—The history of the Ohio Geological Survey is divided into four distinct periods: 1837–1838, when in charge of W. W. Mather; 1869–1888 under J. S. Newberry and Edward Orton; 1889–1894 when the scope of the survey was somewhat extended, but still in charge of Edward Orton; 1900—when the present State Geologist was appointed and a reasonable appropriation granted by the General Assembly. The investigations now in progress are a revision of the areal and stratigraphical geology, by C. S. PROSSER; and a study of the cement, lime, brick, salt and coal industries by various specialists. The first publication issued by the fourth survey is an elaborate detailed discussion of the history, development, utilization, and future prospects of the oil and gas industry of the state. The descriptions are by townships and include a mass of local geological detail. The origin of oil and gas is discussed in a separate chapter.

4. *Geological Survey of New Jersey,* HENRY B. KÜMMEL, State Geologist. Annual Report, 1903. 128 pp., 14 pls.—The work of the New Jersey Survey shows progress along several lines of activity. It has been decided to replace the present topographic map with a new system of non-overlapping sheets. Professor Salisbury is to prepare a report on the surface geology of the southern part of the state. Dr. Weller reports that the Cretaceous presents definitely recognizable faunal zones traceable entirely across the state. Dr. Eastman has made arrangements to complete his studies of the Triassic fish at once. In addition to the usual reports on underground water, mineral resources, etc., a special report is made by C. C. Vermeule on the Passaic floods and a scheme for their control by a throttling dam at Little Falls.

5. *Delta Plains in the Nashua Valley.*—The extensive excavations and borings made by the Metropolitan Water Board in the region of glacial Lake Nashua have furnished unusual opportunities for the study of glacial deposition. In the Technology Quarterly, xvii, No. 1, W. O. CROSBY describes in detail the structure and composition of the delta plains of the Clinton stage and their associated deposits.

6. *The Floods of the Spring of 1903 in the Mississippi Watershed;* by H. C. FRANKENFIELD. U. S. Weather Bureau Bulletin M, 63 pp., 15 charts.—The Mississippi Floods of 1903 exceeded in height any high water on record from Memphis to the Passes. The greatest destruction was at Kansas City, but the villages along most of the western tributaries of the Missouri were affected. As a study of abnormal rainfall and run-off this bulletin is of much value.

7. *Catalogue of the Ward-Coonley Collection of Meteorites;* by HENRY A. WARD. 113 pp. with 10 plates. Chicago, 1904.—It is certainly most remarkable in the history of meteorites that a collection, which is now the largest in the world in number of falls and stands in the first rank with the great collections of Vienna, London and Paris, should have been brought together through the activity and enterprise of one collector and that within a period of ten years. This is true, however, of the Ward-Coonley Collection, the third catalogue of which is now issued. Mr. Ward had already brought together two earlier collections of 170 and 200 falls, respectively, and it was not until 1894 that the present collection was begun. It now numbers 603 falls, with a total weight of about 2500 kilos. During the past four years the increase has been at the rate of 45 falls per year; the catalogue of 1900 showed 424 falls (1399 kilos) and that of 1901 gave 511 falls (1786 kilos). The collection is not simply remarkable in the number of occurrences, but also in the relatively large size of many of the individual specimens. A list, for example, is given of 30 falls, about equally divided between irons and stones, of which the largest single piece is now preserved in the Ward-Coonley Collection. In addition to this point, the introduction of the catalogue calls attention also to some of the remarkable features of the individual specimens and deserves to be studied in detail. The collection is at present placed on deposit in the Geological Hall of the American Museum of Natural History in New York City. The catalogue is handsomely printed, giving not only the locality, details in regard to weight, etc., but also the character of each specimen, as indicated on the scheme of Brezina detailed on a later page. In addition to the main chronological list of the collection, an alphabetical list of all known meteorites with synonyms is given, also a list showing geographical distribution. A series of half-tone plates show some noteworthy specimens, also representations of a number of polished surfaces of the irons, with the figures developed by etching.

8. *Harvard Experiment Station in Cuba.* G. L. GOODALE.—The generosity of Mr. Edwin F. Atkins, of Boston, has placed at the service of the Botanical Department of Harvard University a tract of land and certain buildings near Cienfuegos, which are now employed actively in the attempted solution of a few problems in applied botany. The grounds were first utilized for this purpose a few years ago, when preliminary trials in the artificial production of sugar cane seed were undertaken. For a

short time previous to this, an extensive collection of all the approved varieties of cane then accessible was brought together, and this has been enlarged from time to time, until the sorts now have a very wide range.

From the outset, a good deal of attention was paid to the acquisition of the best kinds of other useful plants, especially those which are adapted to the tropics or those northern plants which can be made to grow more luxuriantly in very warm regions. The establishment was so fortunate as to secure early the services of Mr. C. G. Pringle, as botanical collector. He has devoted much time, with good success, to the selection and forwarding of desirable species from Mexico.

By the end of last year, the number of species had increased so considerably that a new and thoroughly skilled superintendent was placed in charge of the grounds. Mr. Robert M. Grey, the new superintendent, is widely and favorably known as an accomplished hybridizer. He has had placed at his disposal ample facilities for prosecuting his experiments in many directions.

The principal directions of these researches are the following:

(1) Securing the best varieties of cane, by selection and by seeds. In this part of the work, the fullest opportunity is given for the prompt and exact determination in the chemical laboratory of the station, of the sugar-content. Some of the more interesting results have already been published.

(2) Selection and improvement of cotton, ricinus, pineapple, etc., with definite relation to the resistant power of the varieties.

(3) The cultivation of the line of vegetables demanded by the large estates, and finding also a ready market in the cities. This line of study has proved useful and is likely to be more and more highly appreciated by the smaller cultivators with limited capital. This series of studies is placed on an exact basis with regard to cost and profit, in order that the results may be a safe guide to the small farmers and gardeners.

One of the most useful functions of the station has been to show the necessity of extreme caution in entering on large plantings of certain plants which have relentless enemies in the neighborhood, for instance, as a special case, cotton of the usual sorts.

The station was visited winter before last by Mr. J. C. Willis, director of the Royal Botanic Gardens at Perideniya, Ceylon, who has aided us much by his advice. From many sources most generous coöperation has been obtained, and the interesting experiment is now fairly in hand. To indicate somewhat more fully the general nature of the enterprise, I select portions from the latest report of Mr. Grey, which refer especially to the sugar cane, caladiums, pineapples and ricinus.

9. *Report of the Harvard Botanical Station in Cuba for the Month of May, 1904;* by ROBERT M. GREY.—The meteorological observations for the month are as follows: temperature max., day 91°, min. 73°; night 76° and 64°; humidity of the atmosphere 85° to 100°; rainfall 18·04″, for May, 1903, 8·14″.

During the month of May the temperature has been below normal, usually ranging between 82° and 87°, never above 90° during the hottest part of the day. The mornings and evenings have been cool and pleasant with a fine breeze, south to southeast winds prevailing. The barometer has been steady, ranging from 29·87″ to 29·90″. The humidity of the atmosphere has been greater than for the month previous.

The rainfall for the month has been abnormally large. A heavy storm of May 1st lasted about twenty hours, during which time 5·50″ fell, swelling the arroyas and streams to an enormous height, washing out some of the spring planting, and causing much extra work in the garden, which suffered severely. The stream rose eight feet, carrying away some of our botanical plants, which were situated along its margin, and many choice lilies, besides the represser and one bridge. Another severe rainstorm of 4·04″ visited us on May 7, causing a still greater flood, ruining completely bridges, walks and nearly everything along the water course, including our stock Platinal of about ten varieties, some pineapples, fancy caladiums, a part of the tea, Liberian coffee, cocoa, callas, etc.

. . . . Special effort is devoted to propagating, weeding, cleaning and planting shrubbery in our new nursery. We already have a fair lot of laurels, crotons, acalyphas, limes, and about five hundred roses planted out, and much small stock of various kinds which will be transferred later.

The sudden change from dry to wet weather has caused black spot among a few things, such as roses, lettuce, and other stock.

Among the quantities of sugar cane seeds sown this season (over four hundred heads) we have had very poor results. Probably not more than eight or ten seeds in all germinated, and, excepting a single plant, which is still too young to determine positively, these have all died. The remaining one is making a good growth. It came up among seeds of Crystallina collected among the Cinta in the "Chino" and without artificial hybridization. A small portion, each of one hundred heads, was selected and planted together in our small Platinal (since injured by water). The plant germinated about April 27. It has grown rapidly and is now about four inches high, with three fairly characteristic leaves.

I am of the opinion that Cuba is the northern boundary where sugar cane produces flowers, and it therefore seldom perfects seeds of good germinating power in Florida and Louisiana; very little farther north it does not even flower. The flowers on our cane here are perfect and the seeds in many cases reach normal size and appear good, but are very soft and delicate. They are, however, a month later than in the more southern warmer islands and thus do not always have the benefit of the late fall rains to perfect them; no doubt, however, in a succession of years we shall occasionally find favorable seasons in which better luck may attend our efforts.

The new spring plantings of experimental canes came up regular and healthy and are growing well. The varieties of which we had but one or two stock plants have been divided up and transplanted with the rest of the collection, thus bringing all of the experimental canes together in one patch. Since the arrival of the wet weather, what appeared to be "Sereh" or Fan disease on one or two of our Java canes has disappeared, the fanlike appearance being nothing more than stunted growth. Several, however, which showed a lack of chlorophyl in the leaves and were sickly in the roots (probably through weakness) have not grown out of it and will be destroyed as a preventive.

Careful observation among the cane in the field has not brought to light disease of any kind; several plants which had "Rind Fungus" on the dead stock during the early spring and which were marked by us, upon careful examination fail to show traces of any disease in the young canes. They are perfectly healthy and vigorous, which I believe conclusively indicates that the Rind-disease fungus takes possession of dead tissues in exhausted or dead canes when of no further use to the plant.

On December 4, I cross-hybridized Red Spanish and Cuban Queen pineapples; on May 18, when the fruit ripened, I found that not one had perfected any seed. This may be due to the dry season, and I shall experiment further during the wet season when flowers again begin to open. We have disbudded a large per cent of the Cuban Queen pineapples and a great improvement is discernible. The fruits grow larger and mature more rapidly, the flavor is improved and the tissue is softer. This variety usually produces ten to twenty shoots around the base of the fruit, which continue to grow and rob them of the sap essential to their proper perfection. Where disbudding is not resorted to (at least in the winter crop) they take a much longer time to ripen, and they lack flavor.

Colacasia antiquorum, known here under the name of "Malanga" or Tania, is one of the principal articles of food. It is boiled in a similar way to sweet potatoes or "Bonata" and much preferred to it. There are three distinctly marked varieties. The type has dull glaucous green leaves and stems somewhat tinged with purple, and the leaves are rather sharply defined. This is the one commonly cultivated in this vicinity. It is rather insipid in flavor and does not multiply very quickly in the field. The Castilian Malanga, Colocasia antiquorum var. esculentum, is identical with our northern Caladium esculentum; it is of a yellowish color, has a sweetish flavor when cooked, and is much preferred by the laborers. The plant is a stronger and more rapid grower, the leaves are large, irregular, pale green, scarcely glaucous, and the leaf stock is only faintly glaucous. It produces from one-third to one-half more "bulblets" per annum. After giving these two varieties a fair trial I am convinced that the old type can be gradually discarded in favor of this one, and have set out about five thousand in the soltadera for the coming

season, along with as many of the others. They already show a superior growth. This variety is also a valuable florists' plant, and large "bulbs" bring a good price in the market; they could, if desired, be grown here in quantity and at a very fair profit..

The third variety is at present rather scarce, it is a larger and taller grower than either of the above sorts, with a vigorous constitution, but makes very few offsets and does not perfect them so quickly; the flavor is also rather inferior to C. esculentum. The fancy bright foliage Caladiums (closely related to the above) of the C. Schomburgkii, C. Marmoratum, C. bicolor, and C. picturatum type with their hybrids and varieties, grow and increase freely here, and although the market is somewhat limited they can be profitably grown. They do best in a rich humus and require some shade in order to mature big "bulbs" quickly.

The castor-oil plants (Ricinus Zanzibariensis var. Nigra) sowed January 10 ripened their first fruit May 29, and promise a good crop. This is the large black African bean; it is not quite so high in percent of oil as the small native bean, but is several times larger, superior in every other respect, and equally productive, which will more than compensate for this slight difference. The shell is softer and more easily crushed and pressed than the native variety; it also has an advantage over nearly all other varieties in the fact that it is self-shelling in either fire or sunheat, while the native one is not. As a proof of this, I took samples from thirty separate plants and did not find one in which they were self-shelling. Some of the varieties of Arborea and Borboniensis are better in this respect, but I have not been able to test them thoroughly yet.

[The remainder of the report deals with cotton, and with certain vegetables.]

10. *Catalogus Mammalium, tam viventium quam fossilium;* a Doctore E.-L. TROUESSART. Quinquennale Supplementum, Anno 1904. Fasc. I, pp. iv, 288. Berlin (R. Friedländer u. Sohn).—The successive parts of the second edition of this great work have been repeatedly noticed in these pages. The edition was completed in 1897 and an appendix was issued in 1899. A new method has now been adopted to bring the work up to date, viz., the publication of a five-year supplement complete in itself and forming, in fact, a third volume of the *Catalogus;* of this supplement the first part is now issued. The arrangement is such as to show at once what new species have been added and to what groups they belong.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Publication of the Earthquake Investigation Committee in Foreign Languages*, No. 16, 117 pp. Tokyo, 1904.—A detailed discussion is here given by A. IMAMURA of the Milne horizontal pendulum seismograms obtained at Hongo, Tokyo, of earthquakes, about 300 in number, which occurred from July, 1899, to Dec., 1902. Of 49 large earthquakes, 30 of which originated

outside of Japan (East India, Gulf of Mexico, Alaska, etc.), and 19 within Japan, the majority were submarine, only two of the Japan earthquakes having been inland ones. From the observation of these large earthquakes, the average transit velocities of the different phases obtained are as follows: $V_1=13\cdot2$ km. per sec., $V_2=6\cdot8$, $V_3=4\cdot5$, $V_5=3\cdot3$, $V_6=2\cdot8$, $V_7=2\cdot4$, $V_8=2\cdot1$.

2. *Ready Reference Tables*, Volume I. Conversion factors of every unit or measure in use, including those of length, surface, volume, capacity, weight and length, etc., based on the accurate legal standard values of the United States. Conveniently arranged for engineers, physicists, students, merchants, etc.; by Carl Hering, M.E. 16mo, pp. xviii + 196. New York, 1904 (John Wiley & Sons).—The great value to the practical worker of a volume of tables, such as the present, is so obvious that it hardly needs to be insisted upon. The arrangement and typography here are excellent, while the condensed list on the opening pages and the index add much to convenience of use.

3. *University of Chicago: Decennial Publications.*—The first series of these publications consist of ten quarto volumes, viz.: two volumes of reports and eight volumes of investigations representing the research work in the different departments of the University. From volume ix, devoted to mathematics, physics, chemistry, geology, the following memoir, recently issued, is separately printed: The subgroups of the generalized finite modular group, by Eliakim Hastings Moore.

4. *Field Columbian Museum.*—Recent publications include the following: No. 2 of vol. III of the Botanical Series, by Charles Frederick Millspaugh and Agnes Chase, devoted to the plants (Compositæ) of the Peninsula of Yucatan; No. 16, vol. III, Zoological Series, by D. G. Elliot, on mammals collected in Southern California by E. Heller; also No. 3, vol. II, Report Series, giving the Annual Report of the Director for 1902–03.

5. *Publications of the Bureau of Government Laboratories at Manila.*—Bulletin No. 1 of the Entomological Division of the Biological Laboratory, by Charles S. Banks, entomologist, recently issued, discusses the Insects of the Cacao, especially for the benefit of farmers.

Obituary.

Sir Clement Le Neve Foster, F.R.S., professor of mining in the Royal College of Science in London, died on April 19, at the age of sixty-three years.

Professor Alexander W. Williamson, the venerable English chemist, died on May 6, at the age of eighty years.

Mr. Frank Rutley, the well known English petrologist, died on May 16 at the age of sixty-two years.

Professor Émile Duclaux, the eminent French bacteriologist, died early in May in his sixty-fourth year.

Professor Charles Soret, of Geneva, well known for his work in experimental physics, died on April 5th, at the age of fifty years.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XIV.—*On the Ratio of Radium to Uranium in some Minerals;* by BERTRAM B. BOLTWOOD.

THE experiments which will be described in this paper were undertaken with the object of determining the relative proportions of radium and uranium present in certain mineral substances.*

The method which has been used for the quantitative estimation of the radium depends upon the electrical measurement of the radium emanation which is given off when a known quantity of the mineral is dissolved or decomposed by suitable chemical reagents and this solution is allowed to stand for several days in direct communication with a closed glass vessel. Another plan which has also been tried is to decompose the mineral completely in an open vessel and to heat the solution to boiling in order to expel all of the accumulated emanation. The solution was then sealed up in a closed glass vessel and the emanation allowed to accumulate for a given period, at the end of which it was removed and measured†.

The testing of the emanation was carried out in an air-tight electroscope (fig. 1) similar in principle and design to that described by C. T. R. Wilson. It consisted of a rectangular brass case *A*, 15^{cm} high, 10^{cm} wide and $4{\cdot}5^{cm}$ deep. The

* A preliminary notice in which some of the results were given has already appeared in the Engineering and Mining Journal, lxxvii, p. 756, and in the London Nature, lxx, p. 80.

† In a paper by Strutt (Proc. Royal Soc., lxxiii) some measurements of the amounts of radium emanation given off by certain minerals on heating are described. Some experiments which I have made show that samarskite, on heating to low redness, gives off only 10 per cent, and on heating to bright redness only 20 per cent, of the emanation set free when this mineral is completely decomposed with hot sulphuric acid.

walls of this case were 6^{mm} in thickness and were grooved on the edge to a depth and width of 3^{mm}. Two plates of plate-glass 3^{mm} thick fitted closely into the grooves of the case and the joint was made air-tight by the use of hot sealing-wax. The glass plates formed the front and back of the electroscope case. The case was provided with two brass stopcocks, *G*, and carried on the top a glass tube *T*, $2{\cdot}5^{cm}$ in diameter and $7{\cdot}5^{cm}$ in length. The gold-leaf, *l*, was attached to the brass plate *p*, which was 5^{cm} long and 1^{cm} wide, and was soldered to a brass

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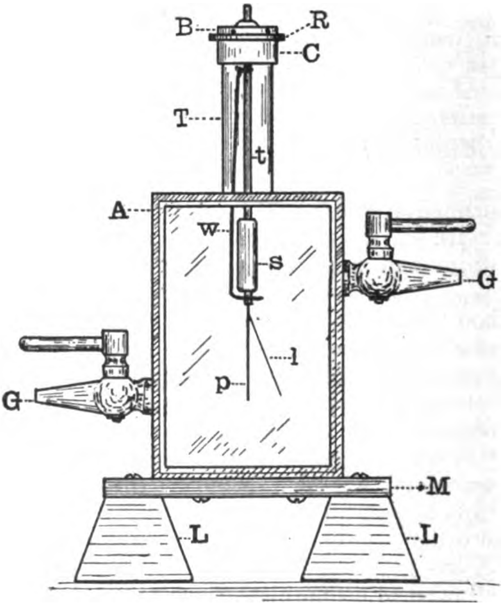

rod $1{\cdot}5^{cm}$ long and 3^{mm} in diameter. The rod *s* of cast sulphur, 4^{cm} long and 1^{cm} in diameter, served as an insulating support for the gold-leaf and was attached at the top to a brass rod 12^{cm} in length and 3^{mm} in diameter. The brass rods were connected firmly to the sulphur support by warming the rods to above the melting point of sulphur and pushing them a short distance into the ends of the sulphur rod. Fitted to the top of the tube *T* was a brass ring, *C*, into which screwed the cap *B*, also of brass. Through the latter passed a short glass tube 1^{cm} in diameter and contracted somewhat at the top. This glass tube was filled with melted sulphur, which was then allowed to solidify. The end of the rod *t* was then warmed and pushed through the sulphur plug until it extended about 5^{mm} beyond

it, and the joint was made still tighter by the application of a small quantity of melted sealing-wax. Suspended by a small hook near the top of the rod *t* was a soft iron wire *w*, which extended to below the sulphur rod and terminated in a loop which surrounded the rod supporting the plate *p*. When hanging in its normal position this wire did not touch the lower rod, but on bringing a small magnet near the tube *T* the wire was deflected and established a metallic circuit between the upper rod and the gold leaf. The plate *p* and the metal portions of its supports were heavily gold-plated to prevent tarnishing. All of the joints and crevices were filled with sealing wax except that between *B* and *C*, which was closed air-tight by a rubber washer, *R*, between them. By unscrewing the cap *B* the gold-leaf and its supports could be removed from the case.

The electroscope was attached by screws to an iron plate, *M*, which in turn was fastened to two lead ingots, *L*, *L*, weighing about seven pounds each. The whole apparatus was therefore very steady and connections could be made at the cocks without fear of altering the adjustment.

For charging the gold-leaf a large stick of sealing-wax was used. This was rubbed lightly on the clothing and approached to the top of the rod *t*, the wire *w* being brought at the same time into contact with the plate *p* by means of a small magnet. On rubbing the rod gently with the sealing-wax a sufficient charge was imparted to the gold leaf to produce the desired deflection. After removing the sealing-wax stick and the magnet, the top of the rod and cap were touched with the finger. This method of charging worked very well during the dry weather of winter and early spring but became troublesome when the air of the laboratory grew moister, and has therefore been superseded by the use of a battery of small storage cells giving a potential of from 300 to 400 volts.

The fall of the gold-leaf due to leak of the electric charge was observed by means of a microscope mounted on a separate support in front of the electroscope. This microscope consisted of a Bausch and Lomb combination of a 2-inch eye-piece and a 1½-inch objective mounted in an ordinary draw-tube. The diameter of the field was about 4^{mm} and the eye-piece contained a glass scale divided into nine divisions, which were further subdivided into tenths; each tenth of a division therefore corresponded to about $0{\cdot}044^{mm}$.

The radium emanation given off by a known weight of mineral substance was collected in the apparatus shown in fig. 2. This was made entirely of glass and consisted of an elongated bulb, *A*, connected by a tube with the smaller bulb *B*, which in turn was connected with the still smaller bulb *C*. A weighed

quantity of the very finely powdered mineral was introduced from a long, thin weighing-tube into the bulb *B*, and, except where the reagent afterwards employed was concentrated sulphuric acid, enough water to cover the mineral was then introduced into *B* from a small pipette. *C* was then filled with the acid used to decompose or dissolve the mineral and, the

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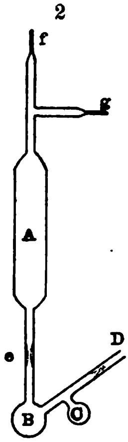


capillary tubes at *f* and *g* having been already closed, the tube *CD* was drawn out into a short capillary and sealed off in the flame of a blast-lamp. At the moment of sealing off, a slight negative pressure was created in the interior of the apparatus by drawing out a small portion of the air through a rubber tube attached at *D*.

The apparatus was tipped until the acid in *C* ran over into *B*, and *B* was then warmed gently until the mineral contained in it had been entirely decomposed. The apparatus was then allowed to stand undisturbed for several days to come into equilibrium and the tube connecting *A* and *B* was then drawn out into a short capillary and sealed off at *e*. The bulb *A*, separated in this manner from the rest of the apparatus, was then allowed to stand for about two hours in order that any rapidly decaying emanation (thorium or actinium) might be entirely removed. The air and radium emanation contained in *A* were then transferred to the electroscope in the following manner: The capillary tube at *e* was first notched with a file and then broken off under the surface of a strong sodium hydroxide solution. Because of the diminished pressure in *A*, several cubic centimeters of the sodium hydroxide solution would be drawn into the bulb. A short rubber tube filled with water was then slipped over *e*. The other end of this rubber tube dipped into a vessel of water. A closed screw pinchcock was then attached to the rubber tube near *e* and the bulb *A* was tilted so that its interior walls were completely wetted with the sodium hydroxide solution. This served to dry the gas somewhat and to remove any acid fumes which might be present. The pressure on the interior of the electroscope was now exhausted to about one-half atmosphere and the stopcocks closed. The capillary tubes at *f* and *g* were notched with a file and *f* was connected with one of the stopcocks of the electroscope by a short section of rubber tubing. The pinchcock at *e* was then opened, the tip of the capillary tube *f* was broken off inside the rubber tube, the stopcock of the electroscope was opened slightly and the air in *A* was drawn over into the electroscope. When the water had risen in *A* until it had reached the junction of the side-tube *g*, the pinchcock at *e* was closed, the tip of *g* was

broken off and the external air was allowed to sweep through the system of tubes until the pressure within and without the electroscope was the same. The stopcock of the electroscope was then closed and the other apparatus disconnected.

For determining the rate of leak or discharge of the gold-leaf, measurements were made of the time required for the gold-leaf to fall through a distance equal to eight divisions of the scale in the eye-piece in the microscope. The time required was recorded by means of a stop-watch divided to fifths of a second. Because of the initial rise in the activity, due to the formation of induced activity within the electroscope, the rate of leak at the end of three hours was chosen in comparing the results obtained with different minerals.

In order to determine the quantity of uranium present in the mineral under examination, the solution in the bulb B was washed out into a beaker and the quantity of uranium determined by one of the ordinary methods of analysis.

The capacities of the two final sections of the apparatus were determined by filling them with water and weighing them, and then weighing them when empty. The average capacity of *A* in the different experiments was about 48^{cc} and the average capacity of the rest of the apparatus was about 9^{cc}. In comparing the results obtained with different minerals it was in general assumed that the distribution of the emanation throughout the different parts of the apparatus was uniform and the volume occupied by the solution was neglected. Since the capacities of the different pieces of apparatus used were in all cases approximately the same and the volumes of the different solutions were all approximately equal, this possibly doubtful assumption would cause no serious error in the results when used for purposes of comparison.

The results obtained with eight different samples of uranium minerals are given in a table below. For decomposing the uraninites strong hydrochloric acid containing a little nitric acid was used, the gummite and uranophane were treated with strong hydrochloric acid and the carnotite was dissolved in dilute (1:1) nitric acid. The sample of samarskite used was obtained in a very finely divided condition by suspension in water and decantation from the coarser material. In this form it could be readily decomposed with concentrated sulphuric acid.

The samples No. 1, 2, 3 and 4 were from North Carolina, No. 5 from Branchville, Conn., Nos. 6 and 7 from Colorado and No. 8 from Saxony.

Between experiments 5 and 6 the adjustment of the electroscope became slightly altered from an accidental movement of the microscope support. A re-determination of the constant

for sample No. 1 under these conditions gave the value of the ratio as 263.

No.	Substance.	Per cent uranium in mineral.	Grams uranium taken.	Leak divisions per min.	Ratio leak to uranium.
1	Uraninite	82·5	0·1067	22·5	211
2	Gummite	66·1	0·0982	20·8	212
3	Uranophane	46·6	0·0671	12·1	181
4	Samarskite	9·8	0·0299	6·4	214
5	Uraninite	83·9	0·0994	20·6	207
6	Carnotite	18·0	0·0258	6·9	267
7	Uraninite	54·6	0·0783	19·8	253
8	Uraninite	48·5	0·0699	16·5	231

The low value of the ratio in the experiment with No. 3 was at first attributed to the fact that this material appeared to give off in the cold a greater proportion of its emanation than the other minerals of the series and that it had, therefore, not reached a state of equilibrium at the time when the emanation was measured. A more careful measurement of the proportion of emanation lost by the cold pulverized samples was made and no differences sufficiently great to explain the low value in No. 3 were obtained. Since the solution of the uranophane had gelatinized on standing in the solution apparatus, owing to the relatively high proportion of silica which the mineral contains, it was thought that this might have been the cause of the low result. Small samples of Nos. 1, 2 and 3 were, therefore, completely decomposed with acids and the resulting solutions evaporated to dryness on the water-bath. The residues were treated with dilute hydrochloric acid and the solutions thus obtained were introduced into apparatus similar to the solution tubes (fig. 2) already described, except that the lower part consisted of a single bulb only. The solutions were then sealed up and allowed to stand for thirty days. At the end of this period the bulb *A* was sealed off and the accumulated emanation transferred to the electroscope. The results thus obtained are given in the following table:

No.	Substance.	Per cent uranium in mineral.	Grams uranium taken.	Leak divisions per min.	Ratio.
1	Uraninite	82·5	0·1227	16·6	135
2	Gummite	66·1	0·0964	13·3	138
3	Uranophane	46·6	0·0686	9·8	143

It is therefore probable that the low value obtained in the first experiment with the uranophane was due to the formation of gelatinous silica. The value of the ratio stands in no direct relation to that obtained in the other series, since the adjustment of the electroscope was again different.

The chief sources of error in the method as described are due to two causes. One of these lies in the fact that the heating of the tube connecting the bulb A with the bulb B naturally warms the gases contained within them and causes a slight alteration in their relative capacities. This difficulty was avoided as much as possible by wrapping both bulbs in wet filter paper before the tube connecting them was heated. The other possible error lies in the fact that some of the minerals tested, particularly Nos. 7 and 8, contained a considerable per cent of sulphides. On treating these minerals with the aqua regia necessary to decompose them, the sulphur of the sulphides was in part oxidized to sulphuric acid and a noticeable quantity of lead sulphate separated from the solution. Although radium sulphate is quite soluble in the strong aqua regia used, it is not impossible that slight traces of this compound were carried down by the precipitated lead sulphate. This would explain the lower values of the ratios obtained with 7 and 8.

I am particularly indebted to Prof. H. A. Bumstead of Yale University for valuable assistance and advice given in connection with this research, and to Prof. S. L. Penfield of Yale University and Dr. Joseph Hyde Pratt of Chapel Hill, N. C. for most generously supplying me with the minerals used in these experiments.

Conclusions.

The quantities of radium present in the uranium minerals which have been examined are apparently directly proportional to the quantities of uranium contained in the minerals.

Since it has been suggested by J. J. Thomson and Rutherford* as very probable that radium is formed by the breaking down of the uranium atom, and if such were the case a final state of equilibrium and a definite proportion between the uranium and radium present in minerals would be expected, these results seem to be of value in furnishing experimental evidence of the actual existence of this fixed relation. It is planned to extend the work to other minerals containing a smaller per cent of uranium and to introduce certain modifications in the method which will considerably increase its accuracy.

New Haven, Conn., June 29, 1904.

*** Radio-activity, Cambridge University Press, 1904.**

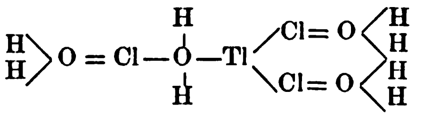
ART. XV.—*The Constitution of Hydrous Thallic Chloride;* by F. M. McCLENAHAN.

[Contributions from the Kent Chemical Laboratory of Yale University—CXIX.]

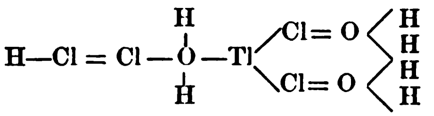
THE nature of hydration and the constitution of the hydrous thallic chlorides have recently been the subject of discussion by Cushman* and R. J. Meyer.† The tetrahydrated thallic chloride $TlCl_3 \cdot 4H_2O$ is easily prepared, and Werther‡, and R. J. Meyer record the preparation of the monohydrate $TlCl_3 \cdot H_2O$, though Cushman was unable to actually isolate this salt. All assert that dehydration cannot be carried beyond the condition of the monohydrate without loss of chlorine. More recently Thomas§ has made record of the complete dehydration of thallic chloride without loss of chlorine by exposure for seventeen weeks over sodium hydroxide *in vacuo*, and ventures the opinion that there is little ground for believing that the relation of one of the molecules of water to the salt is different from that of the others. Meyer maintains that one of the chlorine atoms is not precipitated by silver nitrate and that it sustains a relationship to the complex different from the other two, so that the anhydrous salt may be represented by the symbol $(TlCl)\,Cl_2$. Cushman points out, however, that Meyer's use of Volhard's titrimetric method of analysis was faulty, inasmuch as the thallic salt acts as an oxidizer upon the standard potassium sulphocyanate employed to estimate the silver salt left over after precipitation of the chlorine by a standard solution of silver nitrate, and that in examinations of the filtrates from the usual gravimetric determination (by silver nitrate in presence of a sufficiency of nitric acid), no sign of incomplete precipitation of the chlorine was observed. Cushman concludes that the evidence which supports the writing of thallic chlorides as $(TlCl)\,Cl_2$, as well as all speculation from this point of view, falls to the ground. From experiments in which two specimens of a crystalline non-hygroscopic preparation of the tetrahydrated thallic chloride $TlCl_3 . 4H_2O$ were exposed twenty-one weeks in desiccators, the one over sulphuric acid and the other over phosphoric pentoxide, the conclusion was drawn by Cushman, that it may be taken as certain that the last fourth of the water comes off slowly

* Amer. Chem. Jour., 24, 222 (1900); 26, 505 (1901).
† Zeischer. Anorg. Chem., 32, 72 (1902).
‡ Jour. prakt. Chem., 91, 385 (1864).
§ Compt. Rend., cxxv, 1051 (1902).

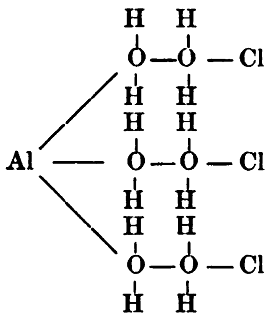
accompanied by chlorine, but that evidence for a definite monohydrate stage is slight. Cushman proposes to account for the relations of water of crystallization in salt complexes upon the hypothesis that oxygen can be quadrivalent and for the tetrahydrated thallic chloride suggests the symbol



and for the crystalline compound obtained by Meyer when the preparation of the hydrous thallic chloride is attempted in presence of hydrochloric acid the related symbol

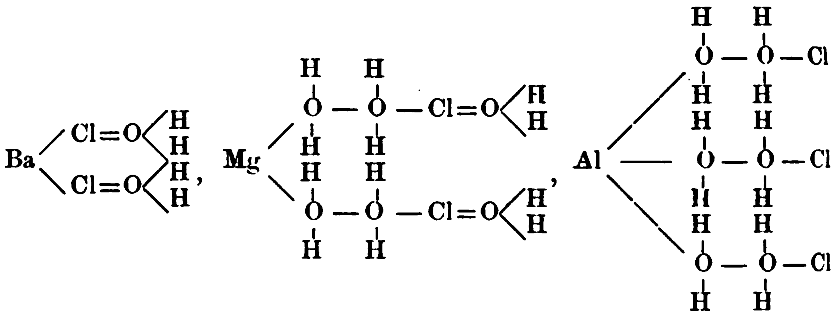


For the molecule of hydrous aluminium chloride Cushman suggests that the water is held within the complex in a manner suggested by the symbol



which brings out the observed fact that water cannot be broken from the molecule without formation of hydrogen chloride, at least in the primary action. The application of Cushman's hypothesis of the quadrivalent linking of oxygen in hydrous salts has been made in a former paper from this laboratory* to the comparative phenomena observed when certain typical hydrous salts, $BaCl_2 \cdot 2H_2O$, $MgCl_2 \cdot 6H_2O$, and $AlCl_3 \cdot 6H_2O$ are dehydrated in air and in an atmosphere of hydrogen chloride. It was shown that the phenomena of these salts are in harmony with the assumption of the symbols

* Gooch and McClenahan: this Journal, xvii, 365 (1904).



in which the molecules of water which may be expelled easily by heat without loss of hydrogen chloride, and at the same rate in air and in hydrogen chloride, are placed outside the chlorine of complex, while those molecules of water which are removed with more difficulty and at a rate affected by the environment, air or hydrogen chloride, are placed inside the chlorine. The suggestion was made that the influence of hydrogen chloride as compared with that of air upon molecules outside the complex is insignificant, while upon molecules of water within the complex the effect may appear variably, according to conditions, (1) in a retardation of dehydration and greater stability of the whole complex, or (2) in acceleration of dehydration with formation of the anhydrous chloride or with hydrolysis implying loss of hydrogen chloride and formation of a residual hydroxide or oxide.

In the present paper, the changes which the thallium chloride $TlCl_3 \cdot 4H_2O$ undergoes when heated in air and in hydrogen chloride have been studied and discussed in relation to the hypothesis of quadrivalent oxygen.

Experimental Part.

Thallous nitrate was dissolved in distilled water and the thallium precipitated as the chloride by means of hydrochloric acid. The precipitate was filtered on asbestos and washed thoroughly of all hydrochloric acid. It was then transferred to a test tube and chlorinated until the last traces of the solid were gone. The solution was evaporated to incipient crystallization and allowed to stand until the clear crystals of thallic chloride appeared. These were removed, dried by means of filter papers, desiccated for a brief period and a sample taken for analysis.

The chlorine in the salt was estimated by the usual silver chloride method, making sure of enough nitric acid. The thallium was estimated as thallous sulphate.* A weighed por-

* Browning: this Journal, ix, 187 (1900).

tion of the salt was transferred to a crucible and a few drops of sulphuric acid added. This was evaporated and the temperature was raised to approximately 200° C. The crucible was cooled in a desiccator and weighed, the weight of the residue was taken to be the acid thallous sulphate. The crucible was again heated and the temperature was raised to that of dull redness. After a suitable period of cooling it was again weighed, and the weight of the residue reckoned as the normal thallous sulphate.

Composition of the Salt.

PREPARATION I.

	Found.	Theory for $TlCl_3 \cdot 4H_2O$.
Thallium............	53·74	53·36
Chlorine	27·81	27·80
Water (by difference)	18·45	18·84
	100·00	100·00

Weighed portions of this salt were transferred to weighed porcelain boats which were placed in combustion tubes passing through a water bath after the fashion of boiler tubes. A slow current of dry air was sent through the tubes kept at 100°. At the end of an hour the boat was removed and weighed. The residue in the boat was dissolved in water containing nitric acid and the chlorine estimated by precipitation and weighing as silver chloride. The calculated composition of the salt is given below.

Dehydration of $TlCl_3 \cdot 4H_2O$ at 100°, in one hour.

Weight of salt taken. grms.	Loss. grms.	Per cent. loss.	Chlorine in residue. grm.	Chlorine in residue.	Loss of Chlorine. Per cent.
0·1572	0·0282	17·94	0·0430	27·36	·45
0·1615	0·0298	18·45	0·0447	27·68	·13
0·2252	0·0402	17·85	0·0620	27·55	·26
0·2221	0·0396	17·83	0·0614	27·65	·16
0·1343	0·0237	17·65	0·0371	27·63	·18
0·1719	0·0308	17·92	0·0473	27·51	·30

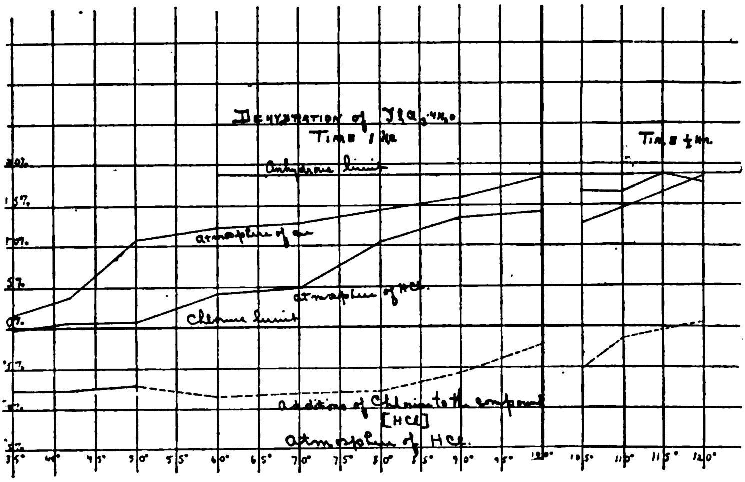
Obviously the hydrolytic decomposition during the process of dehydration at 100° is very small in the case of the hydrous thallium chloride $TlCl_3 \cdot 4H_2O$. By the passage of dry air at 100° over the salt for an hour, nearly anhydrous thallic chloride was obtained, with small loss of chlorine, averaging about 1 per cent of the entire amount in the original salt. The anhydrous residue was crystalline and sparkling in the sunlight, but highly hygroscopic.

Preparation II.

Number.	Weight heated. In air. grm.	Weight heated. In HCl. grm.	Change of Weight when heated. In air. grm.	Change of Weight when heated. In HCl. grm.	Change of Weight when heated. In air. %	Change of Weight when heated. In HCl. %	Chlorine in Residue. In air. grm.	Chlorine in Residue. In HCl. grm.	Chlorine in Residue. In air. %	Chlorine in Residue. In HCl %	Variation in Chlorine from theoretical constitution of salt. In air. %	Variation in Chlorine from theoretical constitution of salt. In HCl. %	Calculated gain or loss of HCl. In air. %	Calculated gain or loss of HCl. In HCl. %	Loss of Water. In air. %	Loss of Water. In HCl. %	Temperature.
1	0·1534	0·1777	−0·0025	+0·0148	− 1·63	+ 8·33	0·0421	0·0628	27·44	35·34	−0·36	+7·54	−0·35	+7·75	− 1·28	− 0·58	35°
2	0·1664	0·1889	−0·0065	+0·0135	− 3·91	+ 7·15	0·0466	0·0671	28·12	35·52	+0·32	+7·72	+0·33	+7·94	− 4·24	− 0·79	42°
3	0·1775	0·1825	−0·0190	+0·0118	−10·70	+ 6·40	0·0508	0·0637	28·62	34·90	+0·82	+7·10	+0·84	+7·30	−11·54	− 0·90	50°
4	0·1243	0·1416	−0·0153	+0·0063	−12·31	+ 4·45	0·0348	0·0514	28·00	36·29	+0·20	+8·49	+0·20	+8·73	−12·51	− 4·28	60°
5	0·2002	0·2086	−0·0253	+0·0065	−12·64	+ 3·12	0·0562	0·0730	28·07	35·00	+0·27	+7·20	+0·28	+7·43	−12·92	− 4·31	70°
6	0·1354	0·1290	−0·0194	−0·0034	−14·33	− 2·64	0·0378	0·0461	27·92	35·74	+0·12	+7·94	+0·12	+8·17	−14·45	−10·81	80°
7	0·1543	0·1594	−0·0245	−0·0122	−15·88	− 7·65	0·0433	0·0533	28·06	33·44	+0·26	+5·64	+0·27	+5·86	−16·15	−13·45	90°
8	0·1537	0·1617	−0·0284	−0·0195	−18·48	−12·06	0·0430	0·0482	27·98	29·81	+ ·18	+2·01	+0·18	+2·07	−18·66	−14·13	100°
Preparation III.																	
9	0·1683	0·1472	−0·0284	−0·0112	−16·88	− 7·61	0·0477	0·0485	28·34	32·95	+0·54	+5·15	+0·55	+5·29	−17·43	−12·90	105°
10	0·1800	0·1442	−0·0300	−0·0189	−16·66	−13·11	0·0503	0·0423	27·94	29·33	+0·14	+1·53	+0·14	+1·57	−16·80	−14·68	110°
11	0·1384	0·1060	−0·0260	−0·0169	−18·79	−15·94	0·0380	0·0300	27·46	28·30	−0·34	+0·50	−0·35	+0·51	−18·44	−16·45	115°
12	0·1157	0·1426	−0·0202	−0·0263	−17·46	−18·44	0·0318	0·0385	27·59	27·00	−0·21	−0·80	− ·21	−0·82	−17·25	−17·62	120°

In the series of experiments next recorded, another preparation of the hydrous thallic chloride was dehydrated at various fixed temperatures in air or in hydrogen chloride, the loss of weight after a definite interval was noted, and the chlorine determined gravimetrically in the residues. The details of the experiments are given in the following statement. The course of dehydration in air and in hydrogen chloride and the action of hydrogen chloride upon the salt are represented in the diagram.

It is to be noted in the first place that although the preliminary analysis indicated a composition of the preparation of the hydrated thallic chloride used in these experiments, the close correspondence with the symbol $TlCl_3 \cdot 4H_2O$, there is an apparent slight gain in the chlorine contents of the chloride



when heated in air nearly throughout the series. This is probably due to an incipient dehydration of the salt before it was weighed out for the work, and the slight deficiency in the total amount of water generally found points in the same direction. Inasmuch, however, as it is a comparison of the behavior of the salt in air with its behavior in an atmosphere of hydrogen chloride which is to be studied, this trifling variation from normal constitution is not important.

It is manifest that the hydrous chloride takes on hydrogen chloride in some degree in an atmosphere of that gas at all experimental temperatures below 100°, and this is without doubt due to the tendency of the salt to form under the conditions of the chlorthallic acid observed by Meyer. At temperatures below 50°, the loss of water in an atmosphere of hydrogen

chloride is small, while the addition of hydrogen chloride is relatively considerable. For this range of temperature in an atmosphere of hydrogen chloride, the constitution of the salt corresponds to the symbol of the chlorthallic acid, $TlCl_3 \cdot 3H_2O \cdot HCl$, with some of the liberated water retained by the hygroscopic compound. At 60° and 70° this hygroscopic water volatilizes and the substance has, approximately, the composition represented by the symbol $TlCl_3 \cdot 3H_2O \cdot HCl$; at 80° the composition suggests the formation of some $TlCl_3 \cdot H_2O \cdot HCl$; while at 90° hydrogen chloride with more water is leaving the salt, and at 100° after an hour's heating, and at 110° after a half hour, the composition corresponds to a mixture of salts, $TlCl_3 \cdot H_2O \cdot HCl$ and perhaps some $TlCl_3 \cdot 3H_2O \cdot HCl$ with $TlCl_3 \cdot H_2O$. At 115° after a half hour the hydrogen chloride is nearly gone and the further dehydration of $TlCl_3 \cdot H_2O$ has begun; and at 120° the product is practically the anhydrous salt, $TlCl_3$, slightly reduced to the thallous-thallic chloride. When a comparison is instituted between the results obtained by heating the salt in air to temperatures above 100°, where the chlorthallic acid is breaking down, and those obtained under similar conditions of temperature in hydrogen chloride, it is obvious that dehydration of the salt $TlCl_3 \cdot H_2O$ is inhibited by an environment of hydrogen chloride.

Reverting now to Cushman's diagram* of the results obtained by long exposure of the hydrated thallic chloride, $TlCl_3 \cdot 4H_2O$, in desiccators at the ordinary temperature, it appears that two molecules of water disappeared from the salt in the course of a week, that the third molecule required for its removal five weeks, and that the fourth molecule vanished only after fifteen weeks more. The general order of the phenomena is in accord with the observations recorded above for the behavior of the salt at higher temperatures during the interval of an hour.

As appears from Cushman's diagram, the preparation of the dehydrated chloride, $TlCl_3 \cdot 2H_2O$, should be very easy. This salt was therefore made the starting point of a series of experiments upon the rate of dehydration in air. A new sample of the chloride, $TlCl_3 \cdot 4H_2O$, was crystallized out and this was desiccated over calcium chloride for three days, until upon analysis the residue was found to have the constitution shown by the symbol $TlCl_3 \cdot 2H_2O$. In this analysis the chlorine was determined, as usual, in the form of silver chloride, precipitated in presence of a sufficiency of nitric acid, and the thallium was estimated as the light yellow thallium chlorplatinate precipitated by chlorplatinic acid from the solution of the thallous salt reduced by sulphur dioxide and weighed on asbestos.

* Loc. cit.

Composition of the Salt.

	Found. I.	Found. II.	Mean.	Theory for $TlCl_3 \cdot 2H_2O$.
Thallium	59·18	59·24	59·21	58·91
Chlorine	30·77	30·72	30·74	30·70
Water (by difference)..			10·05	10·39
			100·00	100·00

Portions of this salt were submitted to dehydration in air in the manner previously described, the boats holding the substance being heated in the tube-bath, generally for intervals of fifteen minutes, and then cooled in a desiccator and weighed. The data of these experiments are shown in the following table and diagram:

Dehydration of $TlCl_3 \cdot 2H_2O$, in Air.

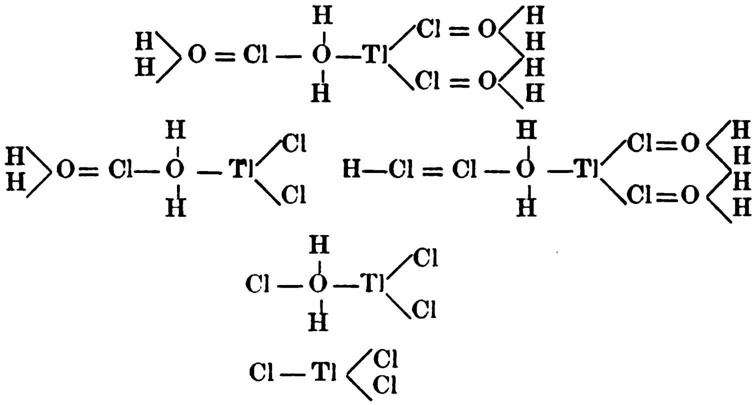
Weight taken. grm.	Loss of Weight. ¼ hr.	¼ hr.	¼ hr.	¼ hr.	¼ hr.	¼ hr.	¼ hr.	¼ hr.	½ hr.	2 hrs.	Chlorine loss. %	Water loss. %
0·2471 grm.	0·0097	0·0134	0·0160	0·0197	0·0221	0·0243	0·0250	0·0255	0·0269	0·0273	----	..
Per cent.	3·92	5·42	6·48	8·00	8·94	9·88	10·12	10·32	10·89	11·05	0·51	10·54
0·3441 grm.	0·0191	0·0248	0·0266	0·0276	0·0308	0·0345	0·0358	0·0371	0·0382	0·0390	----	..
Per cent.	5·55	7·21	7·73	8·02	8·95	10·03	10·40	10·78	11·10	11·33	0·54	10·75
0·3083 grm.	0·0209	0·0241	0·0263	0·0283	0·0302	0·0335	----	----	----	----	----	---
Per cent.	6·78	7·82	8·53	9·18	9·80	10·87	---	----	----	----	0·50	10·37
0·3081 grm.	0·0168	0·0221	0·0237	0·0256	0·0281	0·0306	0·0324	----	----	----	----	----
Per cent.	5·45	7·17	7·69	8·31	9·12	9·93	10·52	----	----	----	0·61	9·91
0·2500 grm.	0·0197	0·0217	0·0235	0·0254	0·0264	0·0279	----	----	----	----	----	----
Per cent.	7·88	8·68	9·40	10·16	10·56	11·16	----	----	----	----	0·45	10·71
0·2250 grm.	0·0177	0·0192	0·0203	0·0221	0·0228	0·0235	----	----	----	----	----	----
Per cent.	7·87	8·53	9·02	9·82	10·13	10·45	----	----	----	----	0·51	9·94

The residues remaining after heating were treated with water, the small amounts of thallo-thallic chloride found in every case and indicating the slight decomposition of the thallic chloride were dissolved by nitric acid, and the combined chlorine was precipitated as silver chloride. The difference between the chlorine thus found and the chlorine of the original salt is tabulated as "chlorine lost" in the process of dehydration. The loss of water was computed as the difference between the total loss observed and the hydrogen chloride corresponding to the chlorine lost. From these results it is obvious that the salt of constitution corresponding to the symbol $TlCl_3 \cdot 2H_2O$ loses the first molecule of water (5·2%) with comparative ease, while the second molecule disappears gradually on prolonged heating.

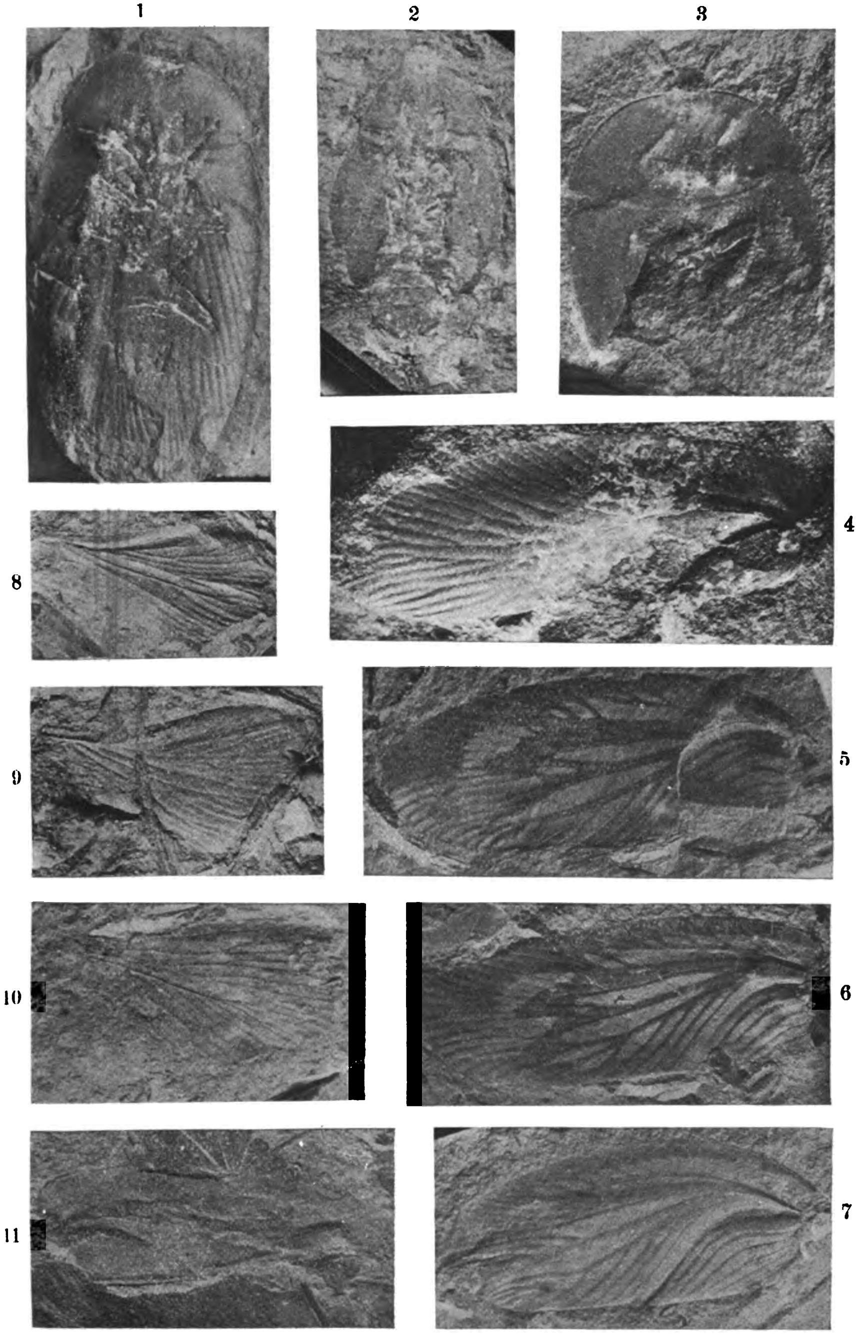
Taking into consideration all the observed phenomena which have been described, it appears that the water in the hydrous thallic chloride $TlCl_3 \cdot 4H_2O$ is held in the complex in three different ways, and that the relation may be reasonably expressed by the symbol $TlCl_3 \cdot H_2O \cdot H_2O \cdot 2H_2O$, the fourth molecule of water being removed less easily in an atmosphere of hydrogen chloride than in air. We have, therefore, the sequence of changes during dehydration represented by the following symbols:

In air.	In HCl.
$TlCl_3 \cdot H_2O \cdot H_2O \cdot 2H_2O$	$TlCl_3 \cdot H_2O \cdot H_2O \cdot 2H_2O$
$TlCl_3 \cdot H_2O \cdot H_2O$	$TlCl_3 \cdot H_2O \cdot HCl \cdot 2H_2O$
$TlCl_3 \cdot H_2O$	$TlCl_3 \cdot H_2O$
$TlCl_3 \cdot$	$TlCl_3$.

These symbols and the phenomena which they cover may be represented upon the hypothesis of quadrivalent oxygen by Cushman's symbol and its derivatives.



The author wishes to express his appreciation of the kind advice of Prof. F. A. Gooch in the preparation of this paper.



Paleozoic Cockroaches.

ART. XVI.—*A Study of the Structure of Paleozoic Cockroaches, with Descriptions of New Forms from the Coal Measures;** by E. H. SELLARDS. (With Plate I and thirty-seven figures in the text.)

CONTENTS.

Introduction.

THE well-known habits of many species of cockroaches, their abundance, and comparatively generalized structure have made them familiar insects and favorite objects of study. They are a characteristic and easily recognized group, separated from all other insects by a number of important structural differences. The body is flat and carried close to the ground. Progression is by a rapid scurrying motion. The tergum of the first thoracic segment, or pronotum, is large, broad, and typically more or less shield-shaped, forming a shelter under which the small flat head can be more or less completely withdrawn. The anal area of the front wing is distinctly marked off by a strong furrow. In recent species the abdomen of the female has undergone considerable modi-

* A paper prepared in the laboratory of paleontology, Yale University Museum, and constituting part of a thesis presented in May, 1903, to the faculty of the Graduate School of Yale University for the Degree of Doctor of Philosophy. As published here, it has been found necessary to omit from the systematic part of the paper, as originally prepared, descriptions of some of the new species, with the expectation that later these will be described elsewhere. The structural and general part of the paper, however, remains unchanged, except for the addition of the brief discussion of the classification of Paleozoic cockroaches, and a life-size restoration of the large cockroach *Archoblattina Beecheri* Sellards.

fication as a result of a specialized arrangement of the reproductive parts. A double fold in the ventral integument forms a characteristic genital pouch, bounded in front and above by the eighth and ninth and perhaps a vestige of the tenth sterna, and below by the enlarged seventh. The main function of this pouch is to retain the egg case while the eggs are being placed in it, and in some species during the period of incubation. The ovipositors have become very much reduced and adapted to serve the specialized function of guiding the eggs into the egg case. The terga of both male and female have also become more or less reduced. As will be seen from the present study, the abdomen and ovipositor, as well as the front and hind wings of the paleozoic cockroaches, are in important respects more generalized than in their living descendants.

Historical Résumé.—The cockroaches of the paleozoic have been known heretofore for the most part from the wings only. Being farther removed from the organic juices of the decaying body, the wings stand a better chance of preservation, especially the more or less coriaceous and resistant tegmina. The body, on account of the large amount of organic matter present, decays more rapidly, and no doubt often served as food for the numerous animals inhabiting the water at that time; hence is much more rarely preserved. The chitinous nature of the wings, on the contrary, renders them comparatively resistant. Moreover, as suggested in an earlier paper, it is probable that some of the small batrachians, dragon flies, or spiders, found in the same deposits, may have acquired the habit of biting off and rejecting the wings, as do the recent dragon flies, bats, and some arachnids. The detached wings are, moreover, readily carried by currents of water into places where permanent deposits are accumulating. The distinction between the paleozoic and recent forms was originally based almost entirely on differences in the front wings.* Some additional knowledge of the structure of other parts of the body has since accumulated from the studies of a considerable number of investigators, among whom are Scudder, Brongniart, Woodward, Deichmüller, Goldenberg, Geinitz, Germar, and others. After the tegmina, the pronotum is the part of the body most commonly preserved, and has been described in connection with the wings by several authors, especially by Scudder and by Brongniart. The habit of concealing the head beneath the pronotum was evidently already developed in paleozoic time, and it is usually rare that any portion of the head is apparent. Woodward detected parts of the head on *Etoblattina Peachii* and *Leptoblattina exilis*, on both of which

*Scudder, Mem. Boston Soc. Nat. Hist., vol. iii, p. 29, 1879.

the top of the head and the line dividing the epicranium may be seen.* But previous to the present study, the eyes and antennæ had not been observed. Surprisingly few hind wings have been described. Brongniart has figured some good ones without description.† Goeppert in his Fossile Flora der permischen Formation, Plate 28, figures under the specific name *Blattina neuropteroides*, what is evidently a small hind wing. In Bulletin 124 of the U. S. Geological Survey, Scudder has described several additional hind wings and reviewed those that had come to his notice up to that time. The legs, with the exception of the tarsus and basal elements, have previously been described in a general way. Deichmüller's *Etoblattina flabellata*, var. *Stelzneri*, preserves on the type specimen the outlines of the coxæ, trochanters, femora, and tibiæ.‡ The *Anthracoblattina sopita* Scudder (*Blattina didyma* Geinitz) shows the femur and tibia of the second pair of legs and the femur, tibia, and a part of the tarsus of the third pair.§ Indications of legs have been noticed by various authors on a number of specimens.

The sword-shaped ovipositor first noticed by Brongniart‖ is one of the most striking differences between paleozoic and recent cockroaches. The presence of the ovipositor can now be verified from American material, and its structure more fully described. Woodward had previously recognized the presence of cerci on these fossils and distinguished the ten abdominal terga, observing that the eighth and ninth were not reduced as in the living forms. The writer in a short paper appearing in the April, 1903, issue of this Journal, gave some additional structural characters of paleozoic cockroaches. Mr. A. L. Melander in the February-March number of the Journal of Geology, 1903, published, however, during the month of April, figures an additional cockroach from Mazon Creek.

Localities and Collections.—Almost all the American material preserving the structure of the body has come either from the Middle or Lower Coal Measures at Mazon Creek, Illinois, or from the Upper Coal Measures at Lawrence, Kansas. In the spring of 1901, the writer discovered the presence of fossil insects among plants collected by Mr. Martin and himself, from the Haverkampf farm near Lawrence.¶ Subsequent

* Geological Magazine, Decade 3, vol. iv, p. 49, 1887; ibid., p. 433.

† Histoire des Insectes Fossiles, atlas, pl. 47, 1893.

‡ Sitzungsb. Gesellsch. Isis, vol. xxxiv, p. 34, 1882.

§ Geinitz, Neues Jahrb. für Min., pp. 4–5, 1875.

‖ Comptes Rendus, Feb. 4, 1889, p. 252; Hist. des Ins. Foss., p. 417, 1894.

¶ A single specimen from a nearby locality in the same formation, found many years earlier by Mr. Joseph Savage, was sent to Lacoe and subsequently described by Scudder as *Etoblattina occidentalis* (Mem. Boston Soc. Nat. Hist., vol. iv, No. 9, p. 410, pl. 32, fig. 4, 1890).

visits to the locality resulted in the discovery of as many as fifty specimens, indicating the comparative abundance of the insects. Later in the summer the Kansas Geological Survey sent a party into the field and obtained in all over two hundred specimens, among them a considerable number of immature forms, or nymphs, or more properly in most cases the sheddings or moults of nymphs. In the fall of the same year, Professor C. E. Beecher very generously placed at the writer's disposal for study the Yale collection of paleozoic cockroaches, especially rich both in nymphs and in adults preserving structural characters. During the past two summers the writer has almost doubled the original number of specimens from the Lawrence Shales, the later collections containing especially instructive nymphs. More recently, Mr. Charles Schuchert has very kindly sent for comparison and study the cockroaches from Mazon Creek contained in the Lacoe collection of the United States National Museum. Mr. L. E. Daniels, through Mr. Schuchert, has loaned from his private collection several specimens from the Mazon Creek locality. During the summers of 1902 and 1903 the writer also obtained a collection of over two thousand fossil insects from a new locality in the Permian of Kansas. Cockroaches in the Kansas Permian are very much in the minority as compared with other families. A considerable number, however, were secured, and these, although not described in detail, have been useful in comparing with those from lower horizons.

Acknowledgments.—The results of an investigation of this kind depend to a considerable extent upon the success of developing and cleaning the fossils. This is especially true of the Mazon Creek specimens, in which the contrast between fossil and matrix is often slight, and the indurated nodules are difficult to work. It was the writer's good fortune in this study to have the advantage of the direction and guidance of the late Professor C. E. Beecher, whose skill in preparing and wide experience with fossils made his suggestions of inestimable value. Moreover, not a little of the skill and ingenuity for which this master of paleontological technique was famous had been expended, with the usual excellent results, on several of the Mazon Creek specimens of the Yale Museum before the collection came into the writer's hands for study. It is also a pleasure to acknowledge indebtedness to Dr. S. W. Williston, Mr. Charles Schuchert and Mr. L. E. Daniels. Dr. Williston encouraged the development of the Lawrence locality, and made the collections belonging to the University of Kansas accessible for study. Mr. Schuchert has contributed not a

little by supplying important types from the National Museum collection. The specimens sent by Mr. Daniels have been of the greatest interest, as adding to the collections from the famous Mazon Creek locality.

Nomenclature used in dealing with the Nymphs.—In attempting the study of a collection of fossil cockroaches, including numerous specimens in the nymph stages, the investigator is met at the outset by the perplexing question of nomenclature. It will rarely be found possible to identify all the nymphs with their respective adult species. When only a few nymphs are to be dealt with, no great inconvenience results from simply referring them to their tribe, or genus, if possible, as immature forms. But when, as in the present instance, a large number are at hand which separate themselves naturally into specific groups, some means of designating a group as a whole becomes practically necessary. Accordingly, in a few instances specific names have been retained or proposed for well-defined species as a means of reference until their connection with adults can be established. Inasmuch as it is difficult, if not impossible, to distinguish the closely related genera of the tribe Mylacridæ in the nymph condition, it has been thought admissible to use the type genus *Mylacris* in a somewhat extended sense, to include the nymphs of the tribe. *Etoblattina* is used in the same way to some extent for the Blattinariæ, although this tribe is more varied, and generic characters seem to appear earlier.

Terminology of the Veins of the Wing.—The system of designating the veins used in the description of species in the present paper is that developed by Redtenbacher and now fortunately coming into general use in entomology. This recognizes in the typical wing five main veins, aside from those of the anal area. It is much to the credit of this system that it is readily applicable to the wings of the simple and comparatively unspecialized insects of the paleozoic. A great deal has been done in recent years to establish the essential unity of the plan of structure of the wing and to discover the homologies of the main veins in the different orders of insects, with the result that many entomologists are now convinced that all winged insects have descended from a common winged ancestor. The complicated arrangement of the veins, so difficult to decipher in the wings of many living adult insects, becomes more and more simple as the phylum is traced toward its point of origin. As paleontological evidence becomes more complete, the steps in the differentiation of the wing can be more closely followed. Inasmuch as the terminology of the veins and their

areas used in this paper is different from that proposed by Heer and employed heretofore in the literature of American paleozoic insects, it has been thought advisable to introduce a sketch of the wing of a typical member of the Paleoblattidæ, giving Redtenbacher's and Heer's names in parallel columns.

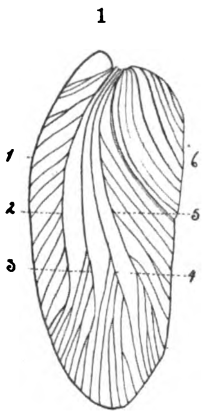


FIGURE 1. — *Gerablattina arcuata* Sellards.

Terminology of the wing veins as developed by Redtenbacher.	Terminology of the wing veins applied by Heer to cockroaches.
1. Costa.	Marginal.
2. Subcosta.	Mediastinal.
3. Radius.	Scapular.
4. Media.	Externomedian.
5. Cubitus.	Internomedian.
6. Anal veins.	Anal veins.

Structure of Paleozoic Cockroaches.

Head.—The head is small, flattened, and capable of being withdrawn partly or entirely beneath the pronotum. The part most commonly seen is the top, or top and front. The sutures dividing the parts of the head are often discernible. The eyes are placed well up toward the top. Their shape is obscured by crushing, but they were large and apparently elongate or reniform. The frons or clypeus posterior is occasionally recognizable (Text-figure 9). The mandibles have not been observed. Supposing them to have been as firmly chitinized as at present, their absence where more delicate structures are preserved is unexpected, and suggests the possibility that the early cockroaches may have fed on soft vegetation, and have had less strongly chitinized mandibles than their omnivorous descendants. The antennæ are long, slender, and many jointed. They are enlarged at the base and united to the head by a circular socket-like attachment (Text-figures 4 and 19).

Thorax.—The segments of the thorax, as in living generalized insects, are not fused or closely united. The pronotum presents considerable variation in shape in the different genera and species, and goes through a regular series of changes during the growth of the individual. At first the posterior border is straight, the lateral angles pointed, and in the Mylacridæ directed backward. As growth progresses the corners become less acutely pointed, then rounded, and the posterior border fuller. The pronotum of the adults of the tribe Mylacridæ is always proportionately broad, but with a rounded posterior border. Among the Blattinariæ the modification progresses

farther, many of the adults of this tribe having an almost circular pronotum. In describing *Etoblattina Peachii* Woodward (*loc. cit.*) refers to a prominent notch in the pronotum. From the illustration given it would seem that the notch was not natural, but caused by the decay and more rapid erosion of the pronotum directly over the head, a feature not uncommon in similar iron-stone nodules from Mazon Creek (Text-figure 7).

Front Wings.—The front wings have been thoroughly studied by Scudder and others, and their distinctive and primitive characters pointed out. The four principal veins of the front wings,—subcosta, radius, media, and cubitus, are distinct to the base. In most living forms two or more of the main trunks disappear by fusion with the adjoining veins, although all four can be seen in their original position in the living nymphs (Text-figure 37). The anal area was well marked off as early at least as the middle of the Carboniferous, but the anal veins, as Goldenberg and Scudder have noted, end with rare exception on the inner border, while, as a rule, among living forms the anal veins end on the furrow. The tegmina were for the most part less coriaceous than those of living forms. Well-developed cross veins are comparatively rare.

Hind Wings.—The hind wings are thinner and more delicate than the front and are much less often preserved. They do not fold longitudinally as do the hind wings of living cockroaches. Cross veins as far as known are absent. The anal area did not present so great a spread as that of modern cockroaches, and, as Scudder has said, does not seem to have been plaited as in almost all modern forms. The costa is submarginal and occasionally gives off one or two superior branches. The veins of this wing are more uniformly developed than in the hind wings of most modern cockroaches. Strength is obtained as in living forms by a subcostal fold. The costal border is nearly straight or a little concave near the base. The inner border is full and well rounded, making the wing broad in proportion to its length (Text-figures 33–36, and Figures 8–10 of Plate I).

Legs.—The legs are not uncommonly preserved, showing either as impressions through the integument or projecting from beneath the body. The second pair is somewhat larger than the first, and the third longer than the second, indicating that progression was by running. The tibia, of some forms at least, was spinous (Text-figures 8 and 14). The femur, on the contrary, was probably smooth, since well-preserved femora show no indications of spines. The first joint of the tarsus seems to have been comparatively long. The number of segments is not distinct on any specimen at hand, but the tarsus was terminated by a claw (Text-figure 23).

Abdomen.—Ten terga are to be seen on the abdomen of both male and female. The projecting edges of the terga are well developed from the third or fourth to the ninth. The tenth tergum is smaller and more or less rounded. The two cerci project from beneath it. The seventh, eighth, and ninth terga are well developed, presenting in this respect a marked contrast to the common existing cockroaches, among which the corresponding terga in both male and female are very much reduced and partly covered by the seventh, even in the later nymph stages. More difficulty is encountered in the study of the sterna. They are seen either in outline through the terga, or, the terga having been removed, are viewed directly. The first sternum, which was doubtless, as in living forms, much reduced and imperfectly chitinized, has not been observed. The third to the ninth can be seen lying beneath their respective terga on a few individuals, presumably males. The seventh sternum of the female is enlarged, rounded, and lies beneath the seventh, eighth, and a part of the ninth terga. The relative position of the parts can be determined from several specimens (Figure 12). The position of the eighth and ninth sterna of the female has not been determined. As Brongniart has suggested (Hist. Ins. Foss., p. 417), the habit of depositing the eggs within an egg case was probably not common at that time. Many of the species doubtless deposited their eggs singly either on the ground or underneath the bark of trees or within small stems. Certain paleozoic ferns in immediate association with cockroaches have been observed to present a row of slits along the rachis, which appear to have been made by such an organ as the ovipositor of the Paleoblattidæ, and, as has been stated in an earlier paper, are indeed strikingly similar to scars seen on the stem of the common *Amorpha fruticosa* (false indigo) and said to be made by katydids.* Nevertheless some genera may have acquired the habit of putting the eggs within egg cases as early as the latter part of the Carboniferous. The writer has recently obtained a fossil from the Upper Coal Measures of Kansas which has a striking resemblance to the egg cases of modern cockroaches (Figure 25).

Ovipositor.—The ovipositor is present on several specimens. The parts of this organ in one very young individual of *Etoblattina mazona* (Figure 11) have apparently not yet united, and present a striking similarity to the early stages in the development of the ovipositor in the Locustidæ, as

* A description of the scars found on the rachis of *Tæniopteris* Brongniart and *Glenopteris* Sellards has been given by the writer in the Kansas Univ. Quart., vol. ix, p. 184, July, 1900; ibid., vol. x, pp. 9-12, Jan., 1901. Similar scars on *Tæniopteris* from West Virginia are described by Fontaine and I. C. White (Perm. Flora, p. 92); and on *Macrotæniopteris* from Virginia by Fontaine (Mon. VI, U. S. G. S., Older Mes. Flora, p. 18, 1883).

figured for *Locusta* by Dewitz.* From this specimen it appears that the ovipositor is composed of probably three pairs, of which the inner is the smallest. In the later stages when the three pairs have become united the component parts are indicated by a groove down the center (Figure 13).

Cerci.—The cerci, which are not uncommonly preserved, vary a good deal in length in the different genera and species, from very long as in *Etoblattina juvenis* to a moderate length as in *E. mazona* and other species. Usually the cerci are directed obliquely to the body; occasionally, however, they stand at right angles, as in *Mylacris anceps.*

Development.—The development, as shown by the numerous nymphs of the collections representing various stages in the ontogeny of single species, is, as in modern cockroaches and other Orthoptera, direct, the young resembling the adults and growth taking place by a succession of moults.

Classification and Description of Carboniferous Cockroaches.

Order *Orthoptera.*

The Carboniferous cockroaches are quite generally recognized as constituting a group of family rank, the Paleoblattidæ, in contradistinction to the modern family Blattidæ. In the disposition of the Paleoblattidæ under the larger divisions, there is, unfortunately, no such uniformity of usage. They are, by some, separated entirely from their modern descendants and included along with other insects in a distinct order, the Paleodictyoptera. By others they are referred directly to the Orthoptera. This diversity of classification, affecting all the paleozoic insects, results not so much, perhaps, from any disagreement as to the essential facts presented, so far, at least, as cockroaches are concerned, as from a difference in the viewpoint from which the facts are interpreted and applied.

The chief contention for the establishment of the order Paleodictyoptera, as expressed by Professor Samuel H. Scudder, is that paleozoic insects as a whole are more closely related among themselves than to their (known) descendants of mesozoic and later times,—a classification in which emphasis is given to the interrelation of contemporaneous but diverging groups, or the lateral relation of organisms, rather than to the lineal or phylogenetic relation in time of particular lines of development. The question of the classification of paleozoic insects in general is not within the range of this paper and will not be touched upon here, except in so far as the principles applied affect the disposition of the Orthoptera as represented by the cockroaches. The gap between the Carboniferous

* Zeit. für wiss. Zool., vol. 25, p. 176, pl. 12, figs. 1-11, 1875.

representatives of modern Orthoptera and the early forms of other orders is, even at that time, an actual one, indicating a considerable divergence in the phylogenetic lines. On the other hand, the apparent break between Carboniferous and later Orthoptera is accidental and due to the fact that not all of the intermediate forms have been preserved, or if preserved have not yet been found. The object of schemes of classification, as is universally conceded, is to express, as far as possible, phylogenetic relations. Following this leading principle, any natural group of organisms should be recognized as extending back in time until a point is reached at which that group coalesces with a group or groups of coördinate rank, or unites with the parent stock. It may often be a matter of difficulty, owing to the imperfect geological record and other causes, to determine the exact point of origin of a group from an ancestral stock. In the case of the Orthoptera, however, the evidence at hand seems conclusive that the order as a distinct phylum is recognizable well into or beyond the Carboniferous. Not only does the body structure of these early forms present the essential features of the Orthoptera, but the development, as is here shown, is in entire agreement with that of modern forms, the young resembling the adults and growth taking place by a succession of moults during which the wings appear gradually.

Super-Family *Blattacea.*

The cockroaches of the Carboniferous, as shown by the foregoing detailed account, are closely related to those of mesozoic and later times. The early forms present not a few generalized characters, such, for example, as the protruding ovipositor, lessening the interval separating them from other primitive Orthoptera. Nevertheless they have already acquired many of those peculiarities which distinguish them from all other insects, notably the rounded shield-shaped pronotum, the small, flat, retractile head, the characteristic strongly delimited anal area of the front wing, the flat bodies, and, without doubt, the peculiar scurrying motion. The indications are that their habitat was much the same. Their constant association with fossil plants, especially ferns, suggests that they were then, as now, fond of moist low places, with abundant vegetation, along the banks of rivers and marshes. Such differences as are found are those resulting naturally from development and specialization, as increased differentiation between the front and hind wing, greater complexity of the wing venation, and the reduction of the ovipositor by specialization. The indications are that the line representing the cockroaches diverges from that of other insects during the early Carboniferous or pos-

sibly before, and is from that time on a distinct and continuous line. The customary separation of the group into an older and a newer part,—the Paleoblattidæ and the Blattidæ, while in a sense artificial, is nevertheless convenient as marking two fairly distinct stages in the development of the phylum. The two families are best included within a single super-family characterized as follows, and for which the term Blattacea is here suggested:

Running Orthoptera; body flat and carried close to the ground; tergum of the first thoracic segment (pronotum) large, broad, typically shield-shaped; head small, flat, inflexed, capable of being more or less completely withdrawn beneath the pronotum; wings differentiated into a more or less thick front wing, and a thinner, broader hind wing; anal area of the front wing marked off by a strong furrow; hind wing not folded in the earlier forms, folded in the later; ovipositor projecting from the abdomen in the Paleoblattidæ, not, or but slightly, projecting in the Blattidæ.

The geological range of the Blattacea is from the Carboniferous to the present. Of the two families included, the Paleoblattidæ extend from middle or early Carboniferous to the close of the paleozoic, possibly lasting over into early mesozoic; the Blattidæ from late paleozoic or early mesozoic, to the present.

Paleoblattidæ.

Paleoblattariæ Scudder, Mem. Boston Soc. Nat. Hist., vol. iii, p. 26, 1879.
Paleoblattidæ Brongniart, Histoire des Insectes Fossiles, p. 416, 1894.

The Paleoblattidæ, the older and more primitive of the Blattacea, are characterized as follows:

Cockroaches with a well-developed and protruding ovipositor. Eggs probably deposited singly in the ground, in stems, or underneath the bark of trees. Hind wings not folded and consequently lacking differentiation into a brownish resistant, and a thin folded part. Anal area never plicated. Differentiation in texture and venation between the front and hind wings less marked than in the Blattidæ, the front wings being, as a rule, less coriaceous and the main veins in both wings more nearly equally developed. Cross veins, except for the reticulation of the membrane, are not common in the front wings, and are unknown in the hind ones.

Description of Genera and Species, including Nymphs.

Mylacridæ.

The Paleoblattidæ are again subdivided into two subordinate groups, the Mylacridæ* and the Blattinariæ. The former

* The term Mylacridæ in use for this group is misleading, since the termination is that accepted for family names. A better term is Mylacrinariæ to correspond with the coördinate division Blattinariæ.

present the more primitive structure and are not known later than the Coal Measures.

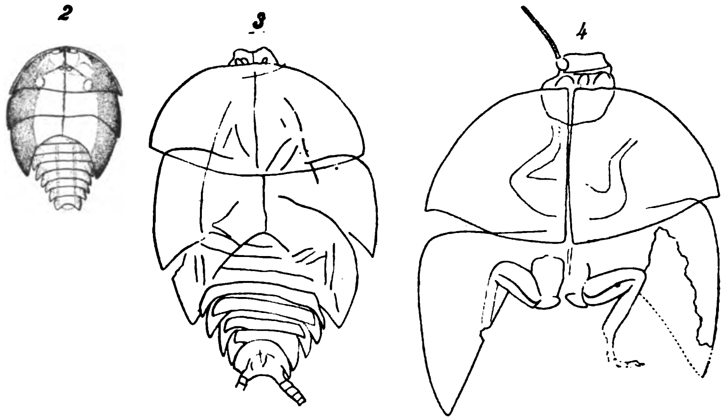
Mylacris.

Scudder, Geol. Surv. Illinois, vol. iii, p. 568, 1868; Mem. Boston Soc. Nat. Hist., vol. iii, pt. 1, p. 40, 1879.

Mylacris diplodiscus. Text-figures 2–4; Plate I, Figure 3.

Dipeltis diplodiscus Packard, Amer. Nat., vol. xix, p. 293, 1885; Mem. Nat. Acad. Sci., vol. iii, p. 145, 1886, pl. v, figs. 2 and 2^a. Schuchert, Proc. U. S. Nat. Mus., vol. xix, p. 672, 1897, pl. lviii, figs. 2–5. Bernard, Natural Science, vol. xi, p. 397, December, 1897. Gahan, ibid., vol. xii, p. 42, January, 1898; Schuchert, ibid., p. 215, March, 1898. Scudder, in Zittel's Text-Book of Paleontology, Eastman's Translation, p. 687, 1900. Melander, Journal of Geology, vol. xi, p. 185, Feb.-March, 1903, pl. v, fig. 6; pl. vii, fig. 6.

Mylacris diplodiscus Sellards, this Journal, vol. xv, p. 309, April, 1903, pl. vii, fig. 8.



FIGURES 2–4.—*Mylacris (Dipeltis) diplodiscus;* all figures twice natural size. Figure 2, after Schuchert. Originals of Figures 2 and 4 in the National Museum; original of Figure 3 in the Yale University Museum.

This species is of much interest historically, having been the first nymph cockroach described from this country, although not recognized as such at the time.* No less than seven specimens of this species in different stages of development have now been obtained. The smallest individual observed, from the National Museum collection, figured by Schuchert (*loc. cit.*), and copied here (Figure 2), is hardly more than one centimeter in length. The pronotum is rounded in front and pointed at the lateral angles. The wing pads appear as lateral extensions of the thoracic terga, the two pairs being very similar in size, shape, and texture. The abdomen is small, short, and narrows

* For a history of *Dipeltis* and a redescription of the type specimen, the reader may consult the short paper by the writer referred to above.

rapidly from about the seventh to the tenth segment. The thorax is unusually large in proportion to the abdomen, being approximately twice as broad and twice as long as the abdomen. A later stage is represented by a specimen 14^{mm} long, and presents much the same proportions. The wing pads have become larger and the front pair now somewhat overlap the second pair. The specimen shown in Figure 3 has reached a length of 2^{cm}, exclusive of the head and cerci. The head as seen on this and other specimens is large; the eyes are here preserved as elongate ovate impressions. The largest specimens, which are presumably approaching maturity, are 3^{cm} in length. The pronotum in these later stages becomes slightly rounded at the lateral angles, the front wings are noticeably larger than the hind, and traces of the venation have appeared. The adult, when identified, will probably be found to have a broad pronotum rounded at the lateral corners, with wings longer than the short abdomen, and resembling in a general way the adults of *M. elongata*, which has, however, a proportionally longer thorax and a more strongly arched boxlike body. The most striking character of the species in its larval stages is the short abdomen and the large, broad thorax. The antennæ, cerci, sterna, and parts of the legs have been observed. The nymphs, not having been identified with the adults, may conveniently retain for the present the specific name already assigned to them. The reference of the species to the genus *Mylacris* is provisional, *Mylacris* being used, as explained above, in a general sense for nymphs of the *Mylacridæ*.*

Formation and Locality.—All the known specimens of this species are from the Coal Measures at Mazon Creek, Illinois.

Mylacris elongata. Text-figures 6–9; and Plate I, Figure 1.

Scudder, Bull. No. 124, U. S. Geol. Surv., p. 41, pl. i, fig. 6, 1895.

The thorax of the nymph referred to this species is large, the larger front wings overlapping the hind ones. The mould of the dorsal surface, from which Figure 6 is made, shows the ten segments of the abdomen. The first to the third terga are reduced. The abdomen is broadest at the fifth segment, and narrows to the tenth. The ninth and tenth terga of this species appear to be closely united, the last being small. A thickened line extends from the ninth across the tenth. The

* Mr. A. L. Melander, in a foot-note accompanying his reference cited in the synonymy above, suggests that the pronotum of this form agrees very well with that of *Promylacris rigida*. From a direct comparison of the types of the two species it seems probable that the pronotum of *Promylacris rigida*, which in the type specimen is distorted, and from which, moreover, the matrix has never been entirely removed, is proportionally less broad than that of *M. diplodiscus*.

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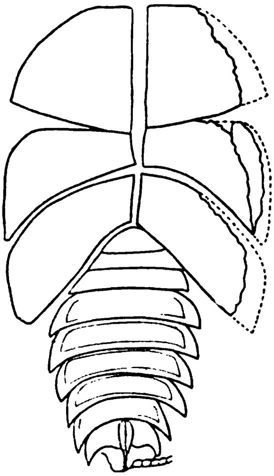

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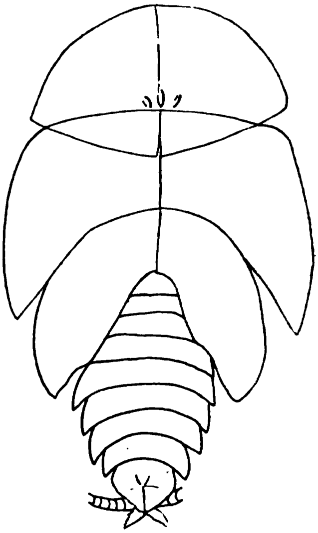

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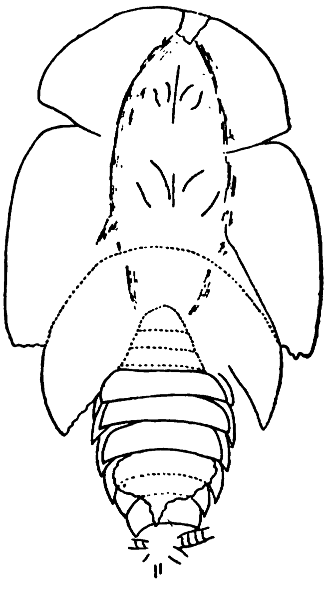

FIGURE 5.—*Mylacris anceps* sp. nov. Cast-off integument of nymph.

FIGURE 6.—Nymph of *Mylacris elongata* Scudder. The illustration is taken from the cast of the dorsal surface. The cerci of this species, as of *M. anceps*, stand at right angles to the axis of the body. The indistinct organ at the end of the abdomen may possibly be the crushed ovipositor.

FIGURE 7.—Same specimen; looking down upon dorsal surface. From this view a depression indicates the outline of the body. The notch in the front of the pronotum is due to erosion, the specimen having been exposed to weathering agents from 1871 to 1880 (see text, p. 119). The whole dorsal surface has suffered erosion during these nine years. Over the abdomen the terga have thus been partly removed, exposing the sterna.

FIGURE 8.—Adult *M. elongata*. The much crushed head is partly exposed. The pronotum, by the time the adult condition is reached, has become, as usual, much rounded at the corners. The dorsal surface has been partly removed to expose the legs and the abdominal sterna.

FIGURE 9.—Head of same specimen.

Figures 5–8 enlarged approximately two diameters; Figure 9, x4. All were obtained from the Coal Measures of Mazon Creek, Illinois. Originals in the Yale University Museum.

cerci are directed at right angles to the axis of the body and are comparatively strong, the joints near the base being twice as broad as long. The body of the insect (Figure 7) has suffered considerable erosion, as a result of which the terga of the abdomen have been removed, except at the edges, thus exposing the sterna. The more rapid erosion of the integument of the thorax over the head and legs reveals the location of these organs.* The sterna as seen in the illustration are of the normal Mylacrid type. The seventh is enlarged and rounded. A portion of some organ, probably the ovipositor, is seen on the inner side of the seventh sternum. At the end of the abdomen of both fossil and mould may be seen what appears to be the two parts of the ovipositor separated and spread open by crushing.

Two adults are referred to this species. The body of the adult exclusive of the head is 36^{mm} long. The abdomen is short as compared with the long thorax. The wings are large, the two pairs being of equal length and much longer than the abdomen. The body is arched transversely. The tegmina have a prominent humeral angle and fit down boxlike over the sides of the body. The pronotum is broad and rounded at the angles and has a full posterior border. The sterna of the specimen figured are visible. As in the nymph, the seventh sternum is enlarged and rounded, and has a depressed line which may represent the impression of the thickened ridge on the ninth tergum. The identification of the two adults with

* The history of the two parts of this specimen is of interest. The mould (Figure 6) was collected by Mr. S. S. Strong and sent to the Yale Museum in 1871 (lot No. 199). The opposite side of the nodule, evidently lost at the time, remained exposed until rediscovered by Mr. Strong and sent to the Yale collection in 1880 (lot No. 1400), having eroded during the intervening nine years to the extent mentioned in the text.

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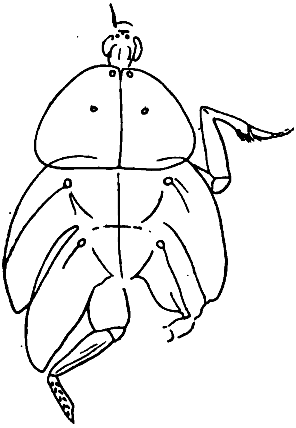

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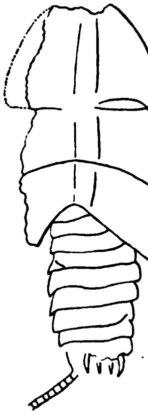

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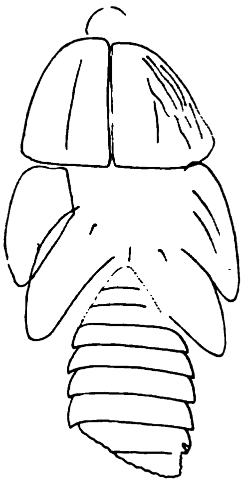

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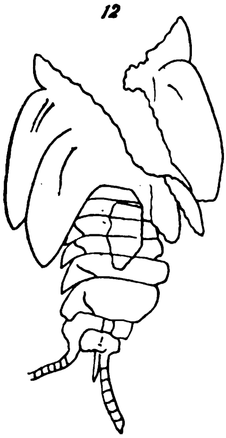

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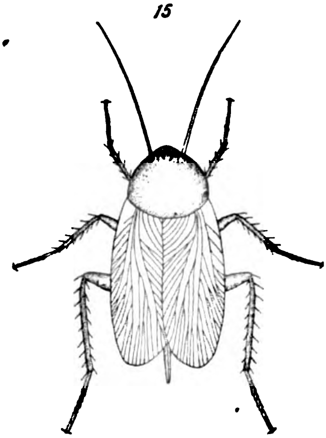

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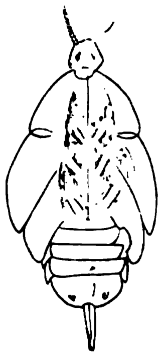

Etoblattina mazona Scudder.

FIGURE 10.—A nymph approaching maturity. The specimen has suffered lateral crushing, causing a wrinkling of the pronotum and giving the abdomen probably an unnatural width.

FIGURE 11.—A small nymph in which the parts of the ovipositor have not yet united. Two pairs are seen, the outer being larger and more curved, the inner smaller and straighter. Some other organs, probably a third pair of ovipositors, are indistinctly seen.

FIGURE 12.—A later stage in which the parts have become united and the ovipositor projects from the abdomen. The enlarged seventh sternum is here seen to lie underneath the eighth, ninth, and tenth terga.

FIGURE 13.—A nymph which, having the terga removed, exposes more of the ovipositor and sterna. The view obtained here as a result of the removal of the terga is of the upper (inner) side of the sterna. The ovipositor is seen to pass on the inner (upper) side of the seventh sternum. The impression of the dorsal surface of this specimen shows the ten terga and the cerci in position, confirming the relative position of the seventh sternum and the eighth, ninth, and tenth terga described for the specimen above (Figure 12).

FIGURE 14.—A nymph approaching maturity.
FIGURE 15.—Restoration of *Etoblattina mazona* Scudder, based upon the type specimen, the wings and pronotum of which are well preserved, and also upon the several nymphs now known preserving practically all parts of the body.
Figures 10–12, x3; Figure 15. natural size; all others, x2. All are from the Coal Measures of Mazon Creek, Illinois. Original of Figure 14 in the National Museum; all others in the Yale University Museum.

Scudder's species *Mylacris elongata* is based on the close agreement in the shape and venation of the tegmina. The connection between nymph and adult is inferred from the relative proportion in size between the thorax and abdomen, the large wings already evident in the nymph, and the similar boxlike shape of the body.

Formation and Locality.—Coal Measures, Mazon Creek, Illinois.

Mylacris anceps sp. nov. Text-figure 5.

The specific name *M. anceps* is proposed for the nymph illustrated in Figure 5, which can not at present be referred to its proper adult species. The most marked characters of the species are its long abdomen and short wings as compared with the species just described. The wings are unusually short considering the size of the nymph. The abdomen is almost or quite as long as the thorax, narrowly elliptical in outline, broadest at the fourth or fifth segment, sloping gradually to the tenth. The tenth tergum is small, and, as in the last species, apparently consolidated with the ninth, the union being strengthened by a strong ridge running down the center. The cerci in this species are also directed at right angles to the axis of the body. The adults will probably be found to have a proportionately broad and long abdomen.

Formation and Locality.—Coal Measures, Mazon Creek, Illinois. Type specimen in the Yale University Museum.

BLATTINARIÆ.

Etoblattina.

Scudder, Mem. Boston Soc. Nat. Hist., vol. iii, p. 56, 1879.

Etoblattina mazona. Text-figures 10–16; and Plate I, Figure 2.

Scudder, Proc. Boston Soc. Nat. Hist., vol. xxi, p. 391, 1882.

Etoblattina mazona is at present the most completely known paleozoic cockroach. A rather full description will therefore be given of several individuals representing stages in the development of the species. A restoration of the species as now known is also attempted. The smallest specimen seen is 15^{mm} long. The body is slender and the two wings appear as

triangular, pointed extensions of the meso- and meta-thoracic terga, equal in size and of a similar texture. The pronotum at this stage is abruptly truncated at its posterior margin. The abdomen is slender and long. The sterna of the specimen are partly exposed. The most remarkable feature in the fossil, giving it an especial interest, is the presence near the end of the abdomen of two pairs of organs and traces of a third, which appear to represent the parts of the ovipositor not yet united (Figure 11). These lie at a level below the edges of the terga and the cerci, but above that of the sterna. The stage of development of the ovipositor represented by this specimen is very similar to that of the young *Locusta* illustrated by Dewitz (*loc. cit.*). A later stage in the ontogeny of the species is represented by Figure 13. The wings are now directed obliquely backward, and are more arched. The dorsal integument of the abdomen is here entirely removed from the seventh sternum and ovipositor and from the rest of the abdomen except at the edges. The parts of the ovipositor have now become united, the line of union being indicated by a furrow. The ovipositor is seen to pass on the inner side of the large seventh sternum, and is incomplete, being broken at the tip. The part preserved is 3^{mm} long. The opposite side of the nodule shows the ten segments of the abdomen complete, together with the cerci. The sterna of the slightly larger individual shown in Figure 12 are also partly exposed. On the inner side of the seventh is what appears to be the ovipositor lying at a lower level and passing beneath the tenth tergum. The abdomen has suffered lateral crushing in fossilization so that the sterna are displaced to the right and the ovipositor lies almost under the right cercus. Figure 14 represents one of the larger specimens of this species. Besides the thorax and wings, the head and two legs are preserved. On the head can be seen the outline of the two rather large eyes. Toward the front of the head are two small paired bumps and between these a smaller elevation. A line at the top of the head divides the epicranial plates. The pronotum at this stage has rounded angles, a full posterior border, and overlaps the base of the front wings. A pair of elevations is seen close to the median line and near the front of the pronotum. A second pair is placed farther back and out from the median line. The pits observed by Schuchert on *Mylacris (Dipeltis) diplodiscus* are doubtless of the same nature. The front and hind wings are as yet scarcely differentiated from each other either in size or texture. They are still united to the terga by their entire base, although a thickened spot, represented in the drawing, indicates the place at which the articulation of the wing is forming. A delicate

median line divides the thorax, which may denote the line of rupture of the integument in moulting and also that the part preserved is here, as in most instances, the cast-off integument. This line is, however, not more marked than that on the thorax of some living nymphs, resulting from the union of the lateral halves of the terga, and the line along which the break ultimately occurs at the time of moulting. The femur, tibia, and tarsus of the first leg on the right side are preserved. The femur is smooth and of about the same length as the tibia. The tibia, on the contrary, is strongly spinous. The first joint of the tarsus is comparatively long; the others are short. The number of joints in the tarsus can not be made out. The left leg of the third pair shows most of the coxa, the trochanter, the femur, and part of the tibia. The femur is stouter than that of the first pair of legs and is likewise smooth. The tibia is slender and preserves the bases of the spines. The trochanter of this leg, also, is seen as a triangular piece uniting the femur and coxa. As in other cockroaches, a progressive rounding during growth of the posterior border of the pronotum is evident, which gives the pronotum of the adult a circular form. The thin texture and the ornamentation of the pronotum are characteristic and serve to confirm the connection of the nymphs and adults.

The restoration given here (Figure 15), is based on the several nymphs of the species and the adult which served as the type specimen, the pronotum of which, more completely uncovered, is here refigured (Figure 16). The cockroach is represented in the resting position. Spines have not been observed on the femur. That the tibia is spinous is shown, however, in Figure 14. The ovipositor of *E. mazona* was apparently of medium length. At the time the restoration given by Professor Scudder was made (Mem. Boston Soc., vol. iii, pl. x, 1882), the presence of the ovipositor and the spinous character of the tibia were unknown.

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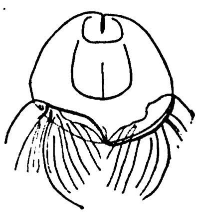

FIGURE 16. — Pronotum of adult of *E. mazona*. × 2.

Formation and Locality.—Coal Measures, Mazon Creek, Illinois.

Etoblattina juvenis sp. nov. Text-figures 17–21.

The most common nymph at the Lawrence locality is a species with large broad abdomen, the terga having well-developed free edges, and the sterna, rounded corners. Two instructive individuals of this species, lying on a small slab, are shown in their relative positions in Figure 17. The dorsal integument of the nymph at the right of the figure has split down the

center and been pushed to each side, thus exposing the basal elements of the legs. The most striking feature is the large size of the second segment,—the trochanter, which, instead of being wedged into the lower angle between the femur and coxa, is apparently joined squarely to the femur. The specimen has been crushed and drawn out laterally, thus causing the trochanters on the left to appear abnormally large and those on the right too small. The median organ in front of the first pair of legs, probably one of the sternal elements, has suffered a similar distortion. The basal part of the ovipositor, 9^{mm} long, is preserved in place. Parts of the body are scattered about

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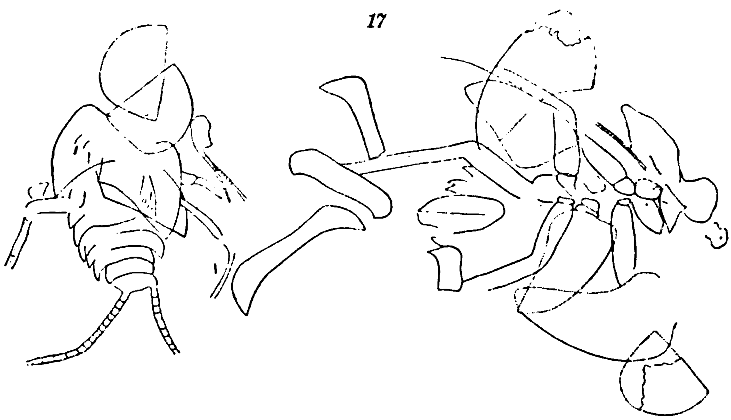

FIGURE 17.—*Etoblattina juvenis* sp. nov.; natural size. Two specimens lying near each other on the same slab. The nymph on the left shows a considerable part of the cerci, which in this species are very long. Both have the legs more or less completely preserved. As a result of crushing, the integument of the nymph at the right has split along the dorsal line, and, spreading laterally, exposed the basal elements of the legs otherwise rarely seen. The species has a large, prominent ovipositor, which is preserved on the specimen at the right; it is badly crushed, however, and its shape poorly defined. Some terga with pointed angles, and sterna with rounded angles, are seen detached and lying between the two nymphs.

Original from the Upper Coal Measures at Lawrence, Kansas, in the writer's collection.

on the slab. Detached terga with their pointed edges, and one of the sterna with rounded edges, are seen lying between the two nymphs. The nymph on the left of the figure is more nearly entire. The head is displaced to the right of the pronotum. The antennæ are very well preserved, but the other structures of the head are too much crushed to be recognized. On the pronotum is seen a circular mark characteristic of the species. Traces of the venation are evident, the cubitus and its branches, as is usual among nymphs, being the most distinct. Parts of the legs are exposed at the sides of the body. The tibia is spinous and the tarsus apparently long. The pointed

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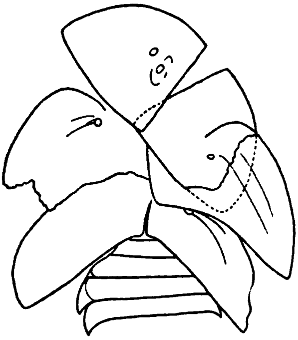

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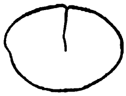

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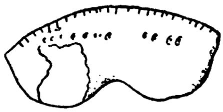

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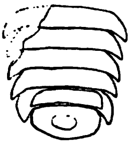

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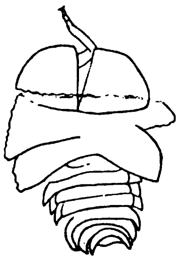

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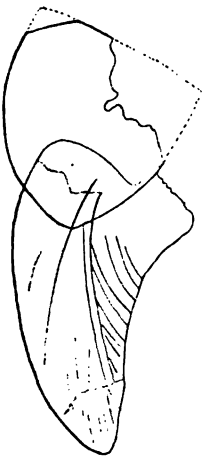

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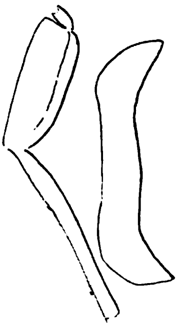


FIGURE 18.—*Etoblattina juvenis* sp. nov. A nymph, of which the thorax and a part of the abdomen are preserved. The abdominal sterna are seen in outline through the terga.

FIGURE 19.—*E. juvenis* sp. nov. A nymph of which a considerable part of the long antennæ and the outline of the head are preserved. The two parts of the pronotum are separated. The absence of spines on the tibia is probably due to imperfect preservation.

FIGURE 20.—*E. juvenis* sp. nov. One wing and half of pronotum of nearly mature nymph.
FIGURE 21.—Trochanter, femur, and one abdominal tergum of nymph.
FIGURE 22.—*Spiloblattina.* Part of abdomen in which are seen indications of color areas resembling those of *Spiloblattina*, to which genus the specimen is provisionally referred.
FIGURE 23.—A small nymph, genus undetermined.
FIGURE 24.—Pronotum of small, probably adult, cockroach.
FIGURE 25.—An undetermined fossil, resembling very much the egg case of cockroaches.
All figures are twice natural size. Original of Figures 18 and 19 in the University of Kansas collection; all others in the writer's collection. All are from the Upper Coal Measures. Figure 23 is from Deer Creek, twelve miles S.W. of Lawrence; others are from Lawrence, Kansas.

free edges of the terga are evident. The cerci, although incomplete, are unusually long. The specimen figured and its counterpart are in the writer's collection. A number of other nymphs of this species have been obtained from the same locality, one of which (University of Kansas collection) is illustrated in Figure 18. The pointed terga and rounded sterna, similar to the detached terga and sternum of Figure 17, are here seen in place. The large nymph, previously figured, is probably also of this species, although the body is larger and more bulky.* The free edges of the terga from the third to the ninth are very prominent. The tenth sternum is rounded. The sterna with their rounded corners are seen in outline through the terga. A part of the strong femur is seen on the right, and a few segments of the antennæ are visible beyond it. The reference of these nymphs to the genus *Etoblattina* is supported by the rounded character of the sterna, which are similar to those of *E. mazona*, and by association, more than half of the adult species from the Lawrence locality belonging to this genus.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas.

Genus Undetermined.

The generic reference of the small nymph (Figure 23) is in doubt. The abdomen has been torn and crushed, but the ten segments can be made out. A few of the sterna seen in outline through the terga are pointed at their posterior corners. A tibia, tarsus, and a part of the femur lie in front of the pronotum. The number of segments of the tarsus can not be made out, but the claw terminating the foot is preserved.

The pronotum (Figure 24) is found detached, and judging from its rounded form probably belongs to an adult.

Formation and Locality.—Both the nymph of Figure 23 and the pronotum of Figure 24 came from the Lawrence Shales, Upper Coal Measures, Lawrence, Kansas.

* This Journal, vol. xv, April, 1903, pl. vii, fig. 5.

[To be continued.]

ART. XVII.—*A Remarkable Parasite from the Devonian Rocks of the Hudson Bay Slope;* by W. A. PARKS.

IT was the writer's privilege, during the summer of 1903, to be engaged on certain geological investigations in the basin of the Moose river, and the opportunity was afforded to do a small amount of collecting from the Devonian area surrounding the southern end of James Bay. This examination was conducted, more particularly, on the Kwataboahegan river, a stream entering the Moose about 12 miles above Moose Factory, which is situated near the mouth of the great river. An account of the fauna of the Lower Devonian rocks there exposed will appear in the Report of the Bureau of Mines of Ontario for the year 1904. In addition to some new species, described in the article referred to, the attention of the writer was drawn to what appeared to be a new species of Platyostoma with a remarkable surface ornamentation. This fossil, which occurs abundantly, has the shape and general appearance of *Platyostoma lineata*, but the surface differs from that species by the possession of a peculiar reticulated ornamentation.

In nearly all cases, casts only of the numerous gasteropods characteristic of the series are found; only one Platyostoma was collected retaining any trace of the shell which shows the ordinary fine lines presented by *P. lineata*. Among the great number of external casts of this species many were seen to present a constant reticulated appearance, as if the outer ornamented part of the shell had been preserved after the inner layer had been dissolved. Such was the conclusion arrived at in the field; but microscopic examination in the laboratory renders this conclusion very improbable. Many of these external casts show the impression of the lines of growth characteristic of the exterior of *P. lineata*, proving that the structure observed is something entirely external to the shell of the gasteropod, and therefore to be regarded as of a parasitic nature. This parasite is most intimately associated with the shell penetrating into the umbilicus and into the deepest parts of the sutures. This fact makes it very difficult to decide that we are not dealing with an external layer as first suggested.

The lower or basal aspect of the parasite is well seen on the casts of the exterior of the Platyostoma. The outer surface was not observed, as the organism is so persistently imbedded in the matrix as to render all attempts to free it abortive.

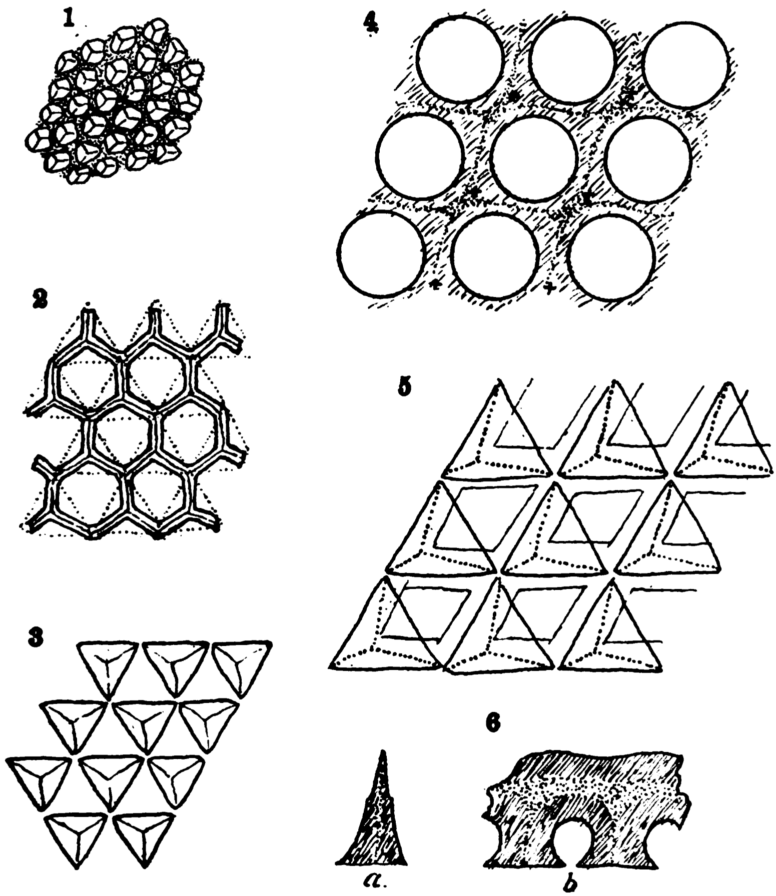
At least two species of this creature occur, differing in the size of the elements composing them and in some minor points

of structure. The finer one is more abundant and better preserved; it is therefore taken as a type of the genus and is described below in some detail.

The cast of the Platyostoma is seen to be covered with round white spots, separated by narrow brownish lines. Three of these spots with the intervals between them occupy the space of one millimeter. They are regularly arranged in lines inclined at a slight angle to the sutures of the host. A line may also be drawn through the centers of the spots inclined at an angle of 60 degrees to the first. On close examination these white spots are found to consist of three elements, separated by minute clear lines. These lines are seen to be uniform in arrangement, being approximately parallel in all the spots; see figure 1. Sections a little higher in the organism show that the pillars decrease in size with a corresponding increase in the intervening matter; they also approach a roughly triangular appearance. Still higher, the contiguous angles of adjacent pillars reach out and unite with each other so as to produce an hexagonal ring with the clear lines of the original pillars forming a continuous line around the middle of the ring. The open center of the ring is occupied by the matrix. It is apparent that each alternate angle of the hexagon represents the position of a pillar, while the other angles are situated at the points of coalescence of adjacent pillars. Higher sections show that this reticulation is continued to the surface of the specimen where the white matter forming the borders of the rings unites and covers the central clear portion. The structure of the reticular network is shown in fig. 2. Tangential sections very near the surface of the reticulation show minute points projecting into the openings of the mesh suggesting the septa of a favositoid coral or certain of the hydrocorallines. A second variety is seen to be represented by an almost similar structure except for the fact that the pillars on ascending become markedly triangular in outline and extremely regular in arrangement. The cross section of this variety at the level where the pillars approach each other is seen in figure 3. The structure of the network is the same as in the first variety. It is quite possible that these two are identical, and that better preservation in the one case has resulted in the retention of the sharp triangular outline of the pillars. It is thought better to include them both in one species.

There is, however, another species, characterized by a much larger mesh in the network and by the fact that the meshes are rhomboidal in outline instead of hexagonal. The ascending pillars show the same three fine clear lines separating the element, but, at a certain level, there is a tendency for one of these lines to become shortened, so that, on the coalescence of

the elements of adjacent pillars, two of the sides of the resulting hexagon are much shorter than the others. A little higher in the skeleton these sides practically disappear, giving in consequence rhomboidal openings in the reticulation. A tangential section of this form is seen in fig. 4, while in fig. 5 is seen a diagrammatic representation of the manner in which the rhom-



boidal meshes originate. In this diagram the center of the pillar is represented by a small cross which will be seen not to conform to the nodes of the reticulation.

In either species it will be observed that the want of symmetry in all directions around the pillars will render vertical sections extremely variable and difficult of interpretation. It is further apparent that vertical sections will cut the reticulated

portion at different points, so that in any one section greatly different appearances will be presented by this part of the skeleton. Vertical sections, however, show that the pillars contract in diameter and the elements composing them gradually arch over and unite, so that certain parts of the network are supported on elliptical arches open at the bottom to the fine brown lines separating the pillars at the base. The interpretation is easy, therefore, that each alternate angle of the hexagonal mesh is supported on a pillar and the alternate angles on a vaulted arch derived from the fused elements of those pillars. Nothing further is revealed by vertical sections, variable as they are, except that the clear matter forming the dividing lines in the pillars expands in the reticulation and ascends almost to the surface of the network, where it is covered by the white matter forming the sides of the meshes. Vertical sections are shown in fig. 6.

The thickness of the entire encrustation in the hexagonal variety is about three-fourths of a millimeter. The rhomboidal species attains a greater height, possibly as much as two millimeters.

The zoological affinities of these parasites is somewhat difficult to determine. The regularly reticulated skeleton at first suggests the Bryozoa, but the peculiar support on the pillars and the structure of the skeletal matter are features that must remove the organism from that association.

The occurrence of the parasite on shells of gastropods naturally leads one to the consideration of Hydractinia, and it is highly probable that our species are closely related to that organism.

Tangential sections of Hydractinia show a network of chitinous fibers with round pillar-like elements at the nodes. The nearer to the base that such sections are prepared the more pronounced are the regularity of the mesh and the individuality of the pillars. Higher sections show that the reticulation becomes more and more irregular as we approach the surface. In the short time spent in examining the skeleton of Hydractinia the writer was unable to cut tangential sections low enough to cross the pillars below the first connecting bars, so that a similarity of mode of attachment can not at present be urged in support of the relationship of our species to Hydractinia.

The two organisms, however, agree in the possession of distinct ascending pillars which give rise to a pronounced reticulation by the coalescence of horizontal elements derived from those pillars. A distinct difference is seen in the fact that our species produce but one layer of meshes which has a considerable vertical extent, whereas Hydractinia repeats this process

and in a more and more irregular manner as it increases in age. Further, the meshes of the network in Hydractinia are practically without any tendency to form tubes, i.e. have no vertical extent. No evidence of polymorphism is to be observed in the species under review. Another point of similarity is seen in the fact that the base of a Hydractinia colony shows a more resistant brownish layer where it is attached to the host; the brown matter lying between the bases of the pillars in our species may well be analogous to this structure in Hydractinia.* The presence of the minute septa-like projections near the surface of the network suggests that the openings of the meshes were occupied by individual hydroids with very short vertical extent. Such an interpretation would place the creature near to Professor Duncan's Stoliczkaria. This relationship can, of course, be maintained only on the supposition that the coenenchyma of Stoliczkaria is entirely unrepresented in our species.†

There is little doubt, therefore, that the new genus may be safely placed under the Hydroida with a considerable resemblance to Hydractinia and a suggestion of the structure of Stoliczkaria. If this relationship is accepted, the study of the present species throws considerable light on the manner in which the horizontal elements arise from the ascending pillars in all this class of creatures. Further, we have but to assume the closing in of the meshes and the repetition of the process of growth to arrive at the origin of the skeleton of that large and diverse group, the Stromatoporoidea.

The preferential parasitism exhibited by this organism at so low a stage as the base of the Devonian is a matter of interest. Further, if we accept its hydroid affinities, and omit the graptolites and stromatoporoids, we have in this creature the earliest of the Hydroida, excepting, of course, the very doubtful Corynoides and Palæocoryne.‡

Tristylotus gen. nov.

Encrusting parasite on species of Platyostoma. Skeleton probably chitinous or partially calcified, consisting of a continuous polygonal reticulation, supported on short pillars. These pillars are composed of three elements, are sub-circular at the point of attachment and triangular above. The reticulation arises by the drawing out of the angles of the triangular pillars and the coalescence of the points thus produced.

Tristylotus—*στυλωτός*, supported on pillars.

* Nicholson & Lydekker—Manual of Palæontology, Vol. I, p. 198.

† Ibid., p. 228.

‡ Ray Society for 1870. Monograph of the Tubularian Hydroids, George James Allman, M.D., p. 170 et seq.

Tristylotus hexagonus sp. nov.

The meshes of the network are hexagonal and small.

Tristylotus rhomboideus.

The meshes of the network are rhomboidal and larger.

The writer is indebted to Professor Ramsay Wright of the University of Toronto for suggestions regarding the affinity of Tristylotus and for the coining of the generic name.

DESCRIPTION OF FIGURES (p. 137).

Tristylotus hexagonus

Fig. 1.—Base of the parasite as it appears on the external cast of Platyostoma. Enlarged 30 times.

Fig. 2.—Diagram to show the origin of the hexagonal network from the triangular pillars. The orginal position and the outline of the pillars are shown in dotted lines. The fine lines show the clear central portion of the mesh. Enlarged about 75 times.

Fig. 3.—Cross section of the pillars in one variety at a level just below where they begin to unite. Enlarged 75 times.

Fig. 6.—(a) Vertical section through a pillar in a direction across the web of the network. (b) Vertical section through two pillars in a direction following the web of the network. Dotted part is the clear central portion. Striated part represents the white matter. Enlarged 30 times.

Tristylotus rhomboideus

Fig. 4.—Tangential section through the reticulated portion. The positions of the centers of the pillars are indicated by small crosses. The dotted portion represents the clear tissue and the striated portion the white matter. The openings in the meshes are shown round in the diagram; this is not strictly correct, as they conform more or less to the shape of the mesh. Enlarged about 60 times.

Fig. 5.—Diagram to illustrate the origin of the rhomboidal meshes. The pillars are indicated by heavy lines. The dotted lines represent the clear lines dividing the pillars into three parts. One of these lines is seen to be much reduced in length. It is this shortening that results in the formation of rhomboidal instead of hexagonal meshes. The outlines of the resulting rhomboidal meshes are shown in fine lines.

Art. XVIII.—*Asterolepid Appendages;* by C. R. Eastman.

The renewed interest which has become manifest in the study of the earliest known fish-like vertebrates bids fair to lead to a clearer understanding of the problems presented, if not indeed to their immediate solution. One of the most puzzling riddles is that concerning the derivation and homology of the pectoral limbs, or "swimming appendages" of the *Asterolepidæ*, the only family of Ostracophores in which such organs occur. Different interpretations of their nature have led to a wide range of opinion in regard to the relations of Ostracophores in general, some authors uniting them with fishes proper and others separating them, some deriving them from the Elasmobranch stem, some from the Crossopterygian, and some even from Arachnids. It is still a mooted point whether Ostracophores and Arthrodires are genetically related, some favoring the retention and others the abolition of the group *Placodermata* as originally proposed by M'Coy. It is upon controverted questions of this nature that a study of Asterolepid appendages may be expected to throw some light.

A variety of opinions has been expressed concerning the probable origin and homology of these organs. Thus, there may be noted: first, the theory that they partake of the nature of Arthropod appendages, on the assumption that Ostracophores are descended from Arthropods; secondly, the theory which explains Asterolepid limbs as the produced and jointed head-angles, or "cornua," of forms like *Cephalaspis;* thirdly, the theory that they are derived from a fixed spine attached to the body, similar to the spinous appendage of *Acanthaspis;* fourthly, the theory that they are derived from the lobate Crossopterygian pectoral fin by a process of reduction and specialization; and lastly, the theory that they are independently derived.

The first two of these hypotheses are evidently founded upon complete misconceptions of the structure and position of Asterolepid limbs, and may be summarily dismissed. The third, which explains them as having become evolved from a fixed spine, presupposes anomalous, if not impossible conditions. Neither can they be looked upon as modified pectoral fin-spines, the remainder of the fin having become atrophied; for no similar case of reduction is known amongst fishes. The fourth suggestion, that these members are derived from specialization of Crossopterygian pectoral fins, has recently been put forward by Mr. C. Tate Regan,* and has not yet been discussed. The foremost objection that may be urged against this theory is that it

* Regan, C. T., The Phylogeny of the Teleostomi (Ann. Mag. Nat. Hist. ser. 7, vol. xiii, pp. 329–349), 1904.

rests upon the unproven hypothesis that Asterolepids are highly modified Crossopterygians. Or, to state the converse proposition, the theory that these two groups are genetically related depends upon whether the modified limbs of the one can be homologized with the lobate pectoral fin of the other, there being absolutely no other characters which can be said to indicate community of origin.

The absence of a lower jaw in Ostracophores, the dissimilar arrangement and structure of their head-bones, armouring of the body, single dorsal fin without either dermal rays or basal supports, heterocercal tail, and absence of both pelvic and pectoral girdles, are characters which emphasize the violent contrast between forms like *Pterichthys* and Crossopterygians. That the latter are descended from a heterocercal ancestor is not to be questioned, but if we admit the soundness of Mr. Regan's conclusion that Asterolepids are highly modified Crossopterygians, how are we to explain their reversion to the primitive heterocercal condition, after having passed through the homocercal? The anterior pair of limbs could hardly have become so highly modified, without the hinder pair having also undergone specialization. But even assuming, for sake of argument, that the pelvic fins have become lost, we should expect to find remnants of a girdle, and in any case some indication of a pectoral arch, corresponding to these structures in Crossopterygians; whereas in fact we do not.

The Asterolepid paddle is not made up of articulated rays, but is simply a muscular extension of the body encased in dermal plates. An appendicular skeleton is wanting, and the external covering plates are attached to the body-armour by a complicated joint, one of the dermal plates being pierced for the passage of nerves and nutrient canals; hence it is clear that in structure and mode of attachment these limbs differ radically from normal Teleost conditions. The fact that Ostracophores possess a much greater antiquity than Crossopterygians also militates against the assumption that they are modified descendants of the latter. It is likewise impossible to reconcile the geological occurrence of the groups to which *Cephalaspis* and *Pterichthys* belong with the view expressed by Mr. Regan that the former is a specialized Asterolepid.

There remains finally the theory, which appears to be not very generally accepted, that Asterolepid limbs have been independently derived. The absence of an appendicular skeleton, and the peculiar mode of attachment of these organs, offer such striking contrasts to the fins of fishes as to make it impossible to conceive of a homology existing between them. Moreover, paired appendages are absent, so far as known, in all other Ostracophores. Either they were formerly present, and

have become lost through atrophy, or else they were never developed except amongst Antiarcha; and if the latter be true, it is easy to see that Asterolepid appendages are unrelated to the fins of fishes, since they originated in a different way and are constructed upon a different plan. They may be regarded with much probability as having developed from a muscular flap, or integumentary extension of the body, being of kindred nature with tactile or clasping organs, or with the frontal spines of Chimæroids. The fact that one of the dermal plates is pierced and otherwise modified for their attachment would seem to indicate that *pari passu* with the development of body-armour, the paired muscular extensions also became encased in plates. But sphinx-like though the problem be as to how and when these structures originated, the evidence appears tolerably certain that they have not been derived from the fins of Pisces proper.

A word may be said in regard to the assumed "close relationship of the *Coccosteidæ* and *Asterolepidæ*," these families being representative of groups which are united by Mr. Regan, together with the Osteostraci, in a single order of Teleostomi. We regard as abortive this author's comparison of *Coccosteus* with *Pterichthys*, which leads him to the conclusion that "the arrangement of the bones of the head, and especially that of the dermal plates of the body, can easily be reduced to a common plan"; and it is manifestly untrue that "in the arrangement of the bones of the cranial roof *Coccosteus* is almost a typical Crossopterygian." A remote superficial resemblance there may be, in that certain plates are symmetrically disposed with reference to the median line, but no real homology can be claimed to exist between the cranial elements of *Coccosteus* and those of Crossopterygians and Stegocephalians. It is impossible to insist too strongly that the jaw-parts of Coccosteids are totally distinct from those of fishes proper, although a parallel exists between them and the dental plates of Palæozoic Chimæroids. Both the upper and lower jaw of Arthrodires consist of purely dermal ossifications, and teeth, properly speaking, are absent. As for the serrations which sometimes occur along the cutting margin in one or both jaws, and function as teeth, these are not structurally differentiated from the supporting bony tissue. Moreover, the lower dental plate ("gnathal" of Dean), instead of being articulated to the cranium, is suspended freely in the soft parts, similarly as in Chimæroids. There is no evidence of pectoral fins amongst Arthrodires, and the lateral spine which is attached to the ventral armour evidently has nothing in common with the pectoral limb of Asterolepids.

The axial skeleton of *Coccosteus*, as depicted by Jækel* with

* Jækel, O., Ueber Coccosteus und die Beurtheilung der Placodermen (Sitzungsber. Gesell. Naturforsch. Freunde, p. 111), 1902. —— Ueber die Ruderorgane der Placodermen (*ibid.* pp. 178–181), 1893.

its complement of ossified ribs, has a purely mythical existence. There are no vertebral rings, the axis being entirely cartilaginous, and on either side of this occur the neural and hæmal arches. It is the latter which Jækel has represented as ribs. Neither is there a pelvic girdle, as claimed by this author, his so-called "ileum" being erroneously interpreted as such, and inverted in position. The narrow, rod-like portion, instead of being directed dorsally, and attached to the cartilaginous axis, in reality projected outward from the body-wall, being in fact merely a modified anterior fin-ray. There is a well-preserved specimen in the Paris Museum of Natural History which shows these structures in their natural position, followed by the remaining fin-rays in regular sequence; nor is this the only example which confirms the interpretation here given.

Another notable difference between Arthrodires and Asterolepids consists in the structure of the dermal plates covering the head and anterior part of the trunk. The body-armour of Asterolepids very likely originated from the fusion of scales, but Arthrodires are naked without exception, and it can be demonstrated that their dermal plates arose within the integument from secretions on both sides of the initial layer. The process was continuous throughout life, a succession of tuberculated strata being deposited upon the external surface of the earlier formed laminae, and bony tissue being added underneath, also in regular layers. Altogether, the distinction between Arthrodires and Ostracophores is so trenchant and far-reaching, that the revival of the group "Placodermata" for their union appears to be an unwarranted and decidedly retrograde movement. Finally, we must beg to differ from Mr. Regan in his conclusion that "the *Coccosteidæ* are Teleostomi, that the *Asterolepidæ* are allied to the *Coccosteidæ*, and that the *Cephalaspidæ* have been derived—through the *Tremataspidæ*—from the *Asterolepidæ*," this view being unsubstantiated by either morphological or palæontological evidence, and contrary to all probability. Nor can we view with much favor Jækel's extraordinary hypothesis* that Coccosteans are ancestral to Chimæroids.

Harvard University, Cambridge, Mass.

* Jækel, O., Ueber Ramphodus, etc. (Sitzungsber. Gesell. Naturforsch. Freunde, p. 392), 1903.

ART. XIX.—*Electrotropism of Roots;* by AMON B. PLOWMAN. (Preliminary Communication.)

IN a brief report some two years ago on the relations of plant growth to ionization of soil* it was suggested that the turning of root tips toward the anode is most easily accounted for by attributing this reaction to the effect of the electrons, or electric charges of the ions, rather than to any mere chemical effects of the atoms.

Since the publication of that report an extensive study of electrotropic phenomena has been carried on at the Memorial Research Laboratory of Harvard University. The results seem to indicate that the explanation advanced in the above-mentioned paper is entirely correct, and further, that the conclusion that "negative charges stimulate, and positive charges paralyze, the embryonic protoplasm of plants," is well founded.

Many kinds of seedlings have been grown both in ordinary soil and by the water-culture method in the presence of an electric currrent, under the most widely varied conditions of temperature, current density and culture composition, with results which are altogether uniform in kind. Even the least perceptible current passing by the roots will in time overcome their normal geotropic tendency, and will turn their tips toward the anode. The passage of a comparatively strong current for only a few minutes will produce a marked curvature after two or three hours. Vigorous roots have been deflected 90° from their downward course in half an hour by a moderately strong current. In such a case as this, if the current is kept on, the roots grow horizontally toward the anode, while if the current is turned off they either continue curving until a complete coil is formed, or they may gradually bend downward again, forming a double curve. In any case the region of the initial curvature is dwarfed in its growth and does not become nearly as large in diameter as the parts either above or just below. There is also always a flattening of the root on the concave side of the curve. This flattened region always remains white when the root tips are fixed in Flemming's fluid, while the other parts, like normal roots, are blackened by a prolonged action of osmic acid solutions.

A study of the histology of such electrically curved roots shows that the protoplasm on the side nearest the anode has been coagulated and killed by the action of the current. The cells are completely plasmolyzed, and their walls are exceed-

* This Journal, xiv, p. 131, Aug. 1902.

ingly thin and much crushed. Where the root has been acted upon for but a very short time only a few of the cortical cells are affected, while for longer action of the current, or more intense current, the affected zone grows wider and wider, until it may involve the entire structure of the root. In every case the boundary line between the affected zone and the normal part is practically a straight line exactly at right angles to the path of the current. The effect is of course most pronounced in the region of most rapid normal growth. Very weak currents tend to check growth in length, and the roots consequently take on a more stocky appearance. They are often actually thicker than the normal roots of the control.

That the results of these experiments are to be attributed to purely chemical causes is rendered highly improbable by the fact that the results are practically uniform, no matter what the ions of electrolysis may be. Distilled water, very dilute acids, bases, and neutral salts all are apparently alike in this relation, their effects differing only with their varying electrical carrying power. Whatever may be the relation of mass action and of chemical and physical affinity to growth under normal conditions,* it would seem that in the present case the all-important factor is the electron or electric charge of the ion, and, more specifically for our purpose, the positive electron, since it is this one which produces the most striking effects. And so far as is at present known, those effects are always in the same direction, viz: paralysis or actual death of the protoplasm exposed to the action of a positive charge. As for the negative electrons, it seems safe to say that in the majority of cases they are neutral in their relation to living cells, and where any effect is perceptible it is in the way of stimulation of the protoplasm.

There is now in preparation for publication in this Journal a fully illustrated report of this series of experiments, together with a consideration of the practical and theoretical bearings of the facts involved.

Phanerogamic Laboratories, Harvard University, June 1904.

* See the article by J. B. Dandeno, this Journal, xvii, pp. 437–458, June 1904.

ART. XX.—*On the Oxygen Absorption Bands of the Solar Spectrum;* by O. C. LESTER.* (With Plates II, III and IV.)

THE present research was undertaken with the object of investigating as fully as possible the structure and extent of the oxygen absorption spectrum. This includes a study of the relations existing between the lines of a band and also between the several bands, taking into account those groups above *a* which do not seem to have been considered before. In order to do this satisfactorily it was necessary to have very accurate measurements of the wave lengths. The best determinations previously made are those of Rowland and Higgs, but neither gives all the lines even of the groups A, B, and *a*. Rowland's measurements are nearly complete for B, but he gives only a few for the other two groups. Higgs gives A and B and up to the ninth pair of *a*, and although he and Rowland agree remarkably well in general upon B, judging from the few lines in A which both have measured the agreement is not so good, there being much greater discrepancies than one would expect from the accuracy claimed for their measurements. Hence it seemed worth while to make new determinations of all, or nearly all, the lines previously measured, and in addition many new lines are given. It is hoped, therefore, that the present determination of the wave lengths, taking into account the best previous results, have both extended and unified the measurements on these bands and rendered them, on the whole, more accurate; thus doing for the absorption spectrum of oxygen what a similar work of M. Eisig† has done for the line spectrum.

Because of the precision which it is possible to attain in the measurement of this spectrum, a careful study of the relations subsisting between the lines and bands furnishes an excellent test of the so-called laws of Deslandres for band spectra. They are briefly as follows:

1. In a given band the intervals from one line to the following in any series, calculated in vibration numbers, are in arithmetical progression, i. e., the lines are connected by a relation of the form

$$\frac{1}{\lambda} = \mathrm{N} = a + bn^2$$

* Abstract of a thesis presented to the Philosophical Faculty of Yale University, June, 1904, for the degree of Doctor of Philosophy. The paper will appear *in extenso* in the September number of the Astrophysical Journal.

† M. Eisig: Das Linienspektrum des Sauerstoffs, Wied. Ann., li, 1894.

where a and b are constants and n takes on all integral values from 0 to n.

2. When several series arise from the edge of a band they are similar in all respects, and all bands belonging to the same substance have the same number of series.

3. In a series of bands the vibration numbers of the edges form a series similar to that of the lines in a single band.

These laws are the most general in their application that have yet been announced. Deslandres tested them on many spectra, although he never published details showing the exactness of agreement. Kayser and Runge* have obtained a general confirmation upon bands of many substances, including those of N, C, CO, CN, and I, but the laws do not apply equally well to all cases and occasionally appear to degenerate into mere interpolation formulæ. The difficulties in the way of obtaining more exact expressions for the laws are in measuring the wave lengths of bands accurately enough to warrant taking into account small variations of the reciprocals, and, in the case of the third law, in finding a long enough series of bands capable of precise measurement. Most of the bands hitherto investigated are in the upper part of the spectrum, where a small error in the wave length causes a large error in the reciprocal.

Measurement of Wave Lengths.

In the measurements of Rowland and Higgs to which reference is made above, both use the same unit, viz. 10^{-7} mm., and their results appear to be equally accurate. For those lines in B and a which both have measured and for which the agreement is ·01 of a unit or closer, the value adopted in the present work is the mean of the two. In case the disagreement is greater than one would attribute to errors of observation, the value adopted is the mean of my own final result and the one which it confirms, provided such agreement is decidedly stronger with one than with the other. In some cases the mean of all three measurements was taken. For the large majority of the lines in A and a the values given are the means of my own and Higgs' results alone. Those of a' and a'' have not been given before. Since ·01 of a unit is about the limit of accuracy in general, it has been thought best to retain only two decimal places in the wave lengths except in the case of B, where many of the lines are taken as Higgs and Rowland give them. It may be added further that the third decimal place rarely affects even the seventh place of the reciprocal.

* Ueber die Spektren der Elemente: Abhandl. der Berl. Akad., 1888–92.

The measurements of the stronger lines were made as usual with a micrometer microscope. Some of the weak lines had to be strengthened by a fine mark placed on the back of the negative. Others were measured from Rowland's charts, care being taken to set on the center of density of the lines. This last method is better for weak lines, although even here a fine mark must sometimes be used, as any magnification by the micrometer causes some of them to melt into the background.

The group a' was first noted by Jewell.* In the "head" or first band of this group, many of the lines appear double and some foreign lines seem to be present. The line 5789·40, which is the "chief line" of this band corresponding to similar lines in A, B, and *a*, has been assumed double, as it is in all the other bands. The only indication of being double actually shown is its greater intensity and a certain flatness of the intensity curve characteristic of close doubles. The uniformity of the two series also calls for a close double at this place.

The approximate positions of many of the lines in the group called a'' were calculated from relations established between the other groups, the observed values differing by less than ·2 of a unit from the calculated. The lines are all extremely weak. Some, though not all of them, appear on negatives taken in zero weather, which indicates that they are not water-vapor lines. The first band of the group begins as usual with a double line, possesses a chief line and a final pair in its proper position, as a glance at the groups as shown in Plate III will show. Probably not all the lines present can be seen. Many are so faint as to be visible only on the charts and then only when they are held in particular positions with respect to the light. Some of the lines are stronger on the corresponding chart of Rowland's first series, which is more intense than the second. No attempt has been made to measure many of the lines of this group closer than the nearest half-tenth, which is readily done by estimation. Blunders and mistakes in calculation for all groups except A have been practically eliminated by the use of verniers made to fit Rowland's charts, which, in spite of irregularities in the map scales, enabled any but small mistakes to be detected at once.

* The Absorption Spectrum of Oxygen; Astron. and Astrophys., xii, 1893.

TABLE I.

Note.—Each band contains two series which go by pairs. Consequently to obtain a single series of a band alternate numbers must be taken.

A		B	
First band.	Second band.	First band.	Second band.
7594·00	7621·27	6867·458	6884·080
95·27	23·53	68·457	86·004
94·28	24·77	67·794	86·982
95·55*	27·30	68·780‡	89·183
94·81	28·52	68·337	90·144
96·06	31·28	69·338	92·614
95·55	32·49	69·144	93·559
96·79	35·47	70·130 §	96·282
96·51	36·65	70·220 §	97·197
97·74	39·86	71·180	6900·196
97·70	41·01	71·528	01·116
98·90	44·46	72·489	04·363
99·14	45·59	73·078	05·263
7600·30	49·27	74·039	08·785
00·80	50·40	74·888	09·677
01·95	54·33	75·830	13·449
02·65	55·45	76·953	14·331
03·80	59·62	77·878	18·365
04·73	60·73	79·275	19·245
05·87	65·14	80·173	23·542
07·05	66·25	-----	24·416
08·20	70·89	-----	28·986
09·57	71·97	-----	29·839
10·72	76·86	-----	34·669
12·33	77·92	-----	35·518
13·45	83·06	-----	40·584
15·32	84·11	-----	41·430
16·41	89·47	-----	46·770
----	90·50	-----	47·580?
----	96·11 †	-----	-----
----	97·13 †	-----	-----
----	03·02 †	-----	-----
----	7704·02 †	-----	-----
----	10·16 †	-----	-----
----	11·16 †	-----	-----
----	17·60	-----	-----
----	18·55	-----	

* Higgs gives also 95·42 and 95·66; probably outside edges of this line.

† These lines taken from Higgs' measurements, and from the uniformity of the series preceding they appear a little large.

‡ This line apparently double.

§ These lines constitute the so-called "chief line." Components difficult to measure accurately.

α		α'	
First band.	Second band.	First band.	Second band.
6276·81	6287·94	5788·33	5796·30
77·66	89·60	(88·55)§	97·76
77·03	90·42	89·00 (double?)	98·43‖
77·86	92·35	88·75	5800·18
77·52	93·15	89·40 (chief line)	00·83
78·29*	95·36	89·40	02·87
78·29	96·34	(89·71)	03·51
79·07	98·64	90·07	05·84
79·31	99·41	90·32 (double?)	06·47
80·08	6302·18	90·97	09·10
80·61	02·95	91·49	09·72
81·37	06·00	(91·78)	12·64
82·16	06·75	92·15	13·25
82·93	10·06	92·96	16·46¶
84·00	10·81	93·60	17·07
84·75	14·40	....	20·58
....	15·14	....	21.16
....	19·02	....	24·94
....	19·75†	....	25·52
....	23·92	....	....
....	24·64	....	....
....	29·10	....	....
....	29·82	....	....
....	34·55	....	....
....	35·26‡	....	....
....	40·28	....	....
....	40·98	....	....
....	46·27	....	....
....	46·96	....	....

α''	
First band.	Second band.
5377·20	5384·27
77·32	85·45
78·00	86·05
78·38 (chief line)	87·50 (double?)
79·45 (double?)	88·10**
80·00	{89·85
80·20 (double?)	90·45} ††
80·85 "	92·55 (covered)
81·40	93·10**
81·97	95·55
	96·10

* Chief line and evidently a close double. Higgs gives also 78·19 and 78·38, apparently the outer edges.

† End of Higgs' measurements. ‡ This line hidden by adjacent heavy line.

§ Lines bracketed do not appear to fit the series. Perhaps foreign.

‖ Covered by heavy line. ¶ Hidden by heavy adjacent line.

** Stronger on old chart.

†† Hidden by a group of five heavier lines, none of which actually cover the positions but the shading renders them invisible.

Relations between Lines and Bands.

The terms "head" and "tail" or "train" used to designate the two parts of the A, B, and *a* groups cannot be taken in this case in the usual sense of these terms as applied to band spectra, and are really misnomers. The spectrum is composed of two series of entirely separate bands instead of a single series, the so-called "heads" forming the first and the "tails" the second. The first series has the appearance of being nearly all "head" and the second all "tail," but the apparent crowding and confusion in the case of the former is due to the distance between the first few pairs being less than their width. That the "head" and "tail" are really separate bands is apparent from the following considerations.

Both "head" and "tail" begin with pairs of the same width, which decrease in width with increasing wave length in the same manner.

No series in a "head" or "tail" is a continuation of a series in the other as it should be if they were parts of the same band. Also, the first and second differences between homologous lines in the "heads" and "tails" form entirely different series as do the ratios of the homologous lines. Further, while there are no lines in places calculated for the tail series extended upward, faint lines appear to be in the proper places for an extension of the head, just as if the first band, instead of fading out gradually as the second does, should drop very suddenly in intensity on approaching the region occupied by the second. That this is apparently what happens is indicated also by the fact that the last line of what is usually considered the last pair in the "head" of B is scarcely half the intensity of its mate and in *a* is less than half. Extending the series of the first bands of B and *a* we find the following agreement between observed and calculated values.

B		α	
Observed.	Calculated.	Observed.	Calculated.
6879·28 } *	----	6284·00 } *	----
80·17 }	----	84·75 }	----
81·80	81·85	86·09	86·11
82·72†	82·72	86·88	86·84
84·65	84·67	88·48	88·49
85·54	85·52	89·20	89·20
87·75	87·74	91·14 (covered)	91·14
88·60	88·57	----	91·83
91·05	91·06	----	----
91·87	91·87	----	----
94·67	94·63	----	----
95·50	95·42	----	----

* Last pair of strong lines. † Hidden by heavy adjacent line.

Indications that the first A band is continued beyond the last strong pair are not lacking though they are not so strong. The other groups are too faint for corresponding lines to be observed in them.

The geometrical relations of both lines and bands are clearly seen in Plates III and IV.

In most spectra it is the vibration numbers which are subject to regular laws rather than the wave lengths, but in this case it makes little difference so far as Deslandres' first law is concerned, which is taken. The first law is but a rough approximation, as is shown by the following application to the second series of the second band of B. The constant b is calculated from the sixth line.

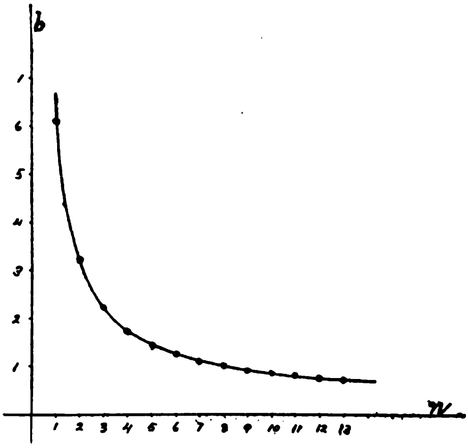
$\frac{1}{\lambda}$ observed.	$\frac{1}{\lambda}$ calculated.	Diff.
14526·27	14526·27	0·00
520·15	524·84	+ 4·69
513·49	520·53	+ 7·04
506·29	513·36	+ 7·07
14498·65	14503·33	+ 4·68
490·42	490·42	0·00
481·70	474·65	− 7·05
472·45	456·00	−16·45
462·72	424·49	−38·23
418·53	319·67	−98·76
406·26	292·92	−123·34

The accuracy of the measurements would allow a variation of only a few hundredths in the last column. The fact is, Deslandres' constant b is not really a constant, at least for this spectrum, as the following values of b, calculated for the different lines of the above series, show:

$b = -6·12$	when $n = 1$	$b = -1·098$	when $n = 7$
$-3·195$	"	$-0·993$	"
$-2·22$	"	$-0·911$	"
$-1·726$	"	$-0·846$	"
$-1·434$	"	$-0·792$	"
$-1·238$	when $n = 6$	$-0·748$	"
		$-0·710$	when $n = 13$

The variations of b are the same for all the bands, except that for the second band series the initial values are always larger than for the first. Also, the values of b for homologous lines of the same band series are nearly constant.

If the values of b for any series are plotted as ordinates and the values of n as abscissæ, curves are obtained which at once suggest a much better law.



The *bn*-curve for sec. series, sec. band, Group B.

The curve, in form, is very nearly an equilateral hyperbola. Assuming it to be such we have

$$bn = k = \text{const.}$$

This, however, is not quite true, but if a correction is made as follows,

$$bn - \frac{n}{c} = k$$

then k is almost exactly constant. Substituting this value of b in Deslandres' formula we have

$$N = a + kn + cn^2.$$

That is, the correction for Deslandres' law is of the first order in n instead of being as usual of a higher order; the constant k is very large compared with c. Both c and k are different for the different series but their variations are small.

The increased accuracy of the new formula is shown by its application to the same series of B calculated above by Deslandres' law. The differences only are given here corresponding to the third column above.

0·00	+0·01	$k = 5·86$
+0·00	−0·04	$c = ·2611$
+0·02	−0·07	
+0·05	+0·01	
+0·00	−0·02	
+0·02	−0·05	
+0·01	−0·16	

The second differences of the new formula are constant as they are in that of Deslandres, and it is evident from the near approach to constancy observed in the second differences of both N and λ, that some law based on this property is the true one. That the lines follow some very definite arrangement is seen from the smoothness of the bn-curves and from the smallness of the differences between the observed and calculated values. It is quite probable that the proposed formula will be found to represent the line series of other band spectra more closely than the old. This I have not as yet investigated. Assuming the proposed law to be exact we have on the other hand a criterion of the accuracy of the measurements of the wave lengths. It is quite likely that if the series were longer the formula would need an additional term, possibly one depending on the wave length. This is a matter for further investigation. The formula may have some theoretical importance also, as the formulæ so far deduced theoretically have not contained the first power of n.

Deslandres' second and third laws are only approximate for this spectrum but a correction for them could not be obtained with certainty, owing, in the case of the third law, to the shortness of the band series.

The points of chief importance in the foregoing discussion may be summarized as follows:

1. The general accuracy of the determination of the wave lengths in the groups A, B, and a has been greatly increased and the series which compose them considerably extended.
2. The band a' has been measured and its relation to the other groups studied for the first time, and in addition a new band a'' has been observed and studied at $\lambda = 5377{\cdot}2$.
3. The oxygen absorption spectrum has been shown to consist of two distinct series of bands instead of one, the series of bands occuring in pairs just as do the series of lines in a band.
4. Deslandres' first law has been shown to be entirely inadequate to represent the line series of the several bands and a modification is proposed which gives results agreeing with the observed values to about the limit of error of the measurements.

In conclusion I wish to express my thanks to Prof. A. W. Wright, whose kindly interest and criticism have been of great benefit throughout this investigation, and through whose aid the excellent photographs of the spectrum were obtained.

Sloane Physical Laboratory, Yale University.
May 1, 1904.

EXPLANATION OF PLATES II TO IV.

Plate II.

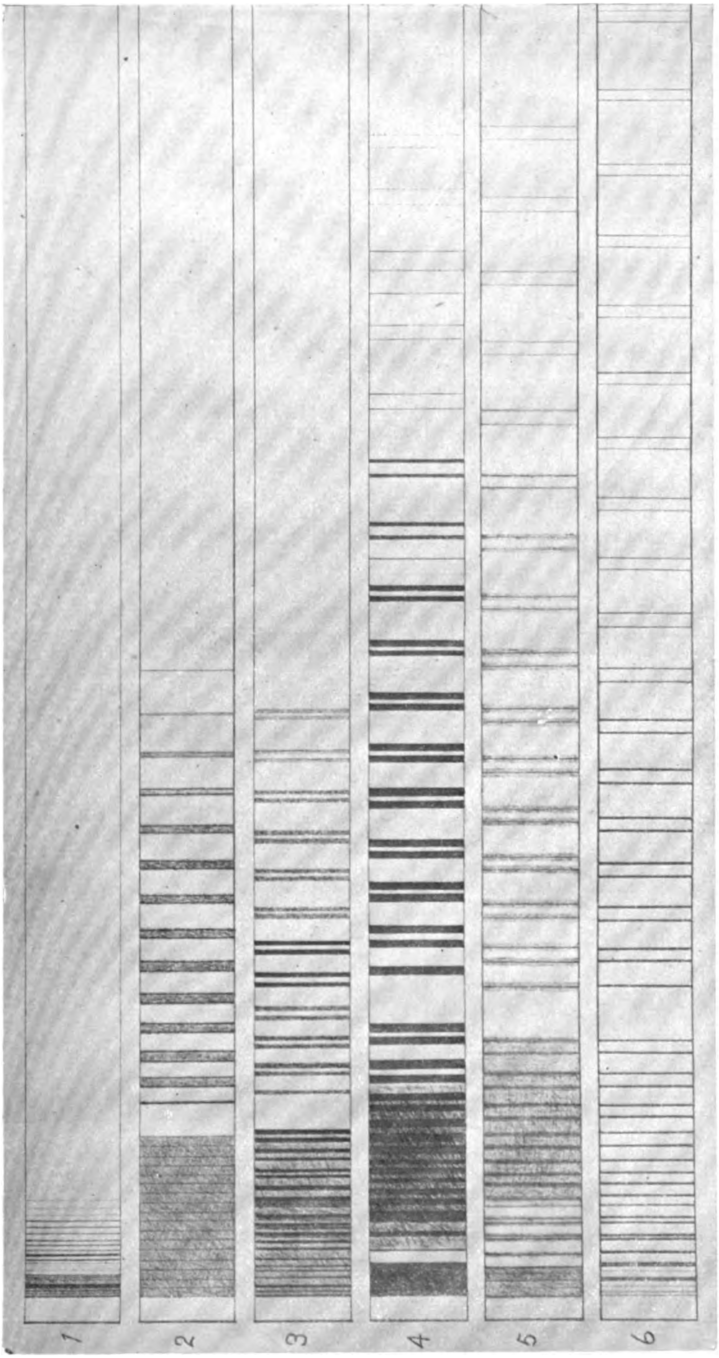
1.—A group ; Kirchhoff. Prismatic spectrum.
2.—A " ; Thollon. " "
3.—A " ; Langley. Grating spectrum.
4.—A " ; Piazzi Smyth. " "
5.—A " ; Cornu. " "
6.—A " ; Drawn from photographs with large Rowland grating in Sloane Laboratory. The last three pairs added from measurements of wave lengths. Comparison was made with Higgs' photographs of A which are probably the best yet taken. The drawing shows all details except the "secondary series." The eighteenth pair is cut off.

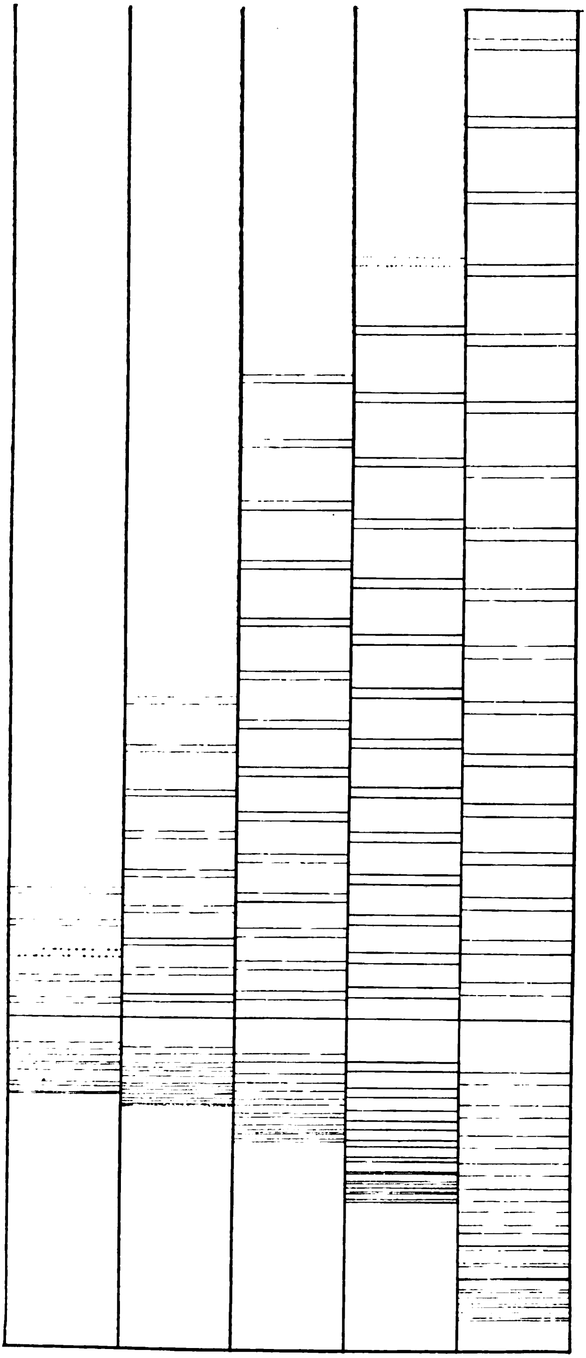
Plate III.

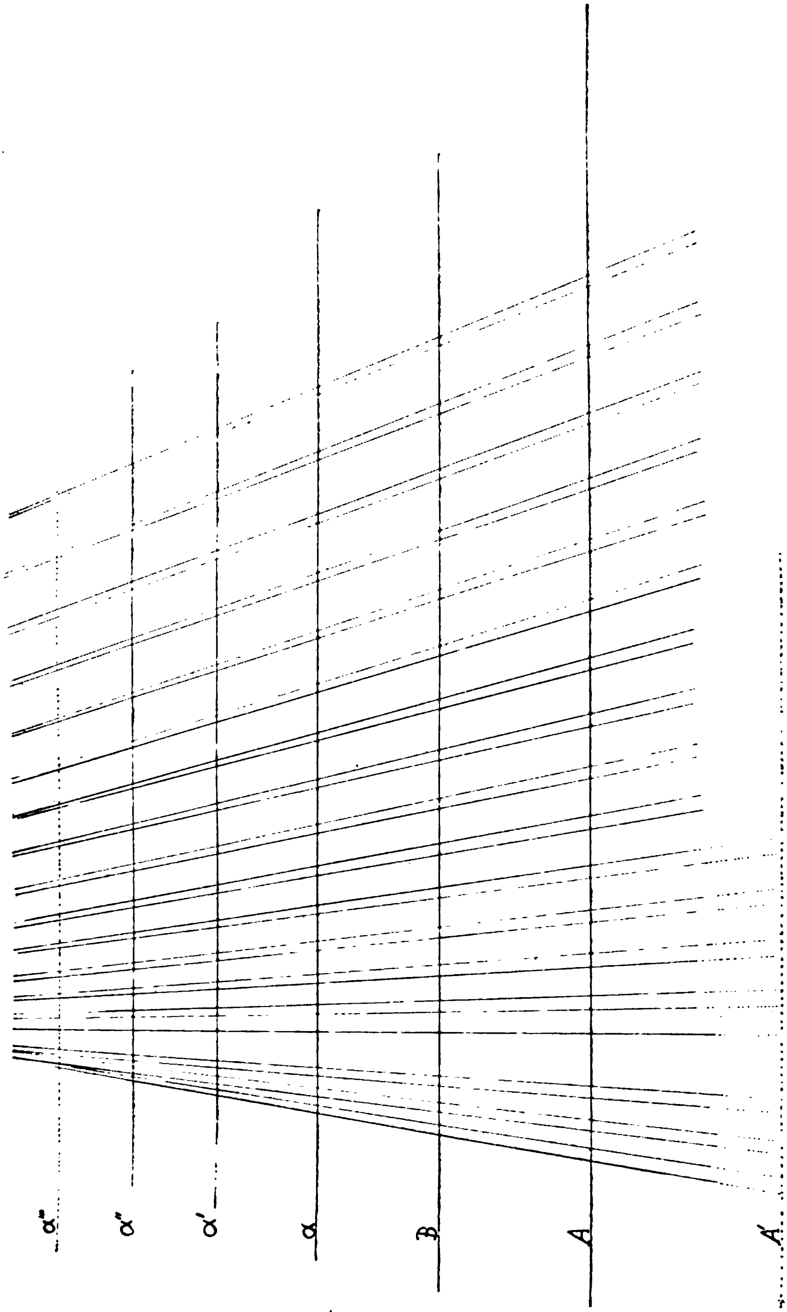
The groups as represented in Plate III are drawn from the measurements of the wave-lengths. Beginning with A, they are arranged in order, one above the other, with the first lines of the second bands forming a straight line. This pyramid-like grouping of the bands is especially effective in showing the symmetrical arrangement of the pairs from group to group and their decreasing width from A to a''.

Plate IV.

The distance between the lines marked A and B is 4^{cm}, representing the distance in wave lengths between these two bands. The other horizontal lines are drawn at distances proportional to their distances in wave lengths from A. Plotted in this way the corresponding lines of the several bands fall almost exactly in a straight line, this being especially true for those lines whose wave lengths are most accurately measured.






α'''
α''
α'
α
B
A
A'

SCIENTIFIC INTELLIGENCE.

I. Geology and Natural History.

1. *United States Geological Survey.*—The following publications have recently been received:

Professional Paper No. 11.—The clays of the United States east of the Mississippi River; by Heinrich Ries. 287 pp., 9 pls., 11 figs. The origin of clay, its composition, varieties and uses is discussed and its geologic distribution described. The greater part of the paper is taken up with a detailed description and discussion of the clay deposits and the clay industry of the states east of the Mississippi.

No. 12.—Geology of the Globe Copper District, Arizona; by F. L. Ransome. 165 pp., 27 pls., 10 figs.

The oldest rocks of the Globe district are crystalline schists of pre-Cambrian age, which, together with intruded masses of granitic rocks, form the core of the Pinal range. Upon these schists lie a series of shales, conglomerates and quartzites, varying in thickness from 500 to 800 feet, which have been assigned to the Cambrian. Overlying these is a series of limestones with a maximum thickness of about 400 feet. They range in age from Devonian to Upper Carboniferous. In addition to the sedimentary rocks there are large masses of diabase, which were intruded chiefly in the form of silts between the sedimentary beds. Later still, another volcanic eruption brought extension masses of dacite into the region.

The structure and topography of the region is largely dependent upon the great number of faults found in the district. Mr. Ransome says, "Probably few equal areas of the earth's surface have been so thoroughly dislocated by an irregular network of normal faults, and at the same time exhibit so clearly the details of the fractioning."

Mining in the district was commenced in 1874. The early work was done on silver and gold deposits, the copper ores which are the predominant ones to-day not having been seriously worked until after 1881. Since then the quadrangle has produced approximately 120,000,000 pounds of copper.

The copper ores belong to two mineralogical classes: (1) oxidized ores being mostly cuprite, malachite or chrysocolla, and (2) sulphide ores being mostly pyrite and chalcopyrite. The first group has furnished the major part of the ore up to the present. The ore bodies exhibit various forms and may be classed as (1) lodes, (2) masses in limestone and (3) irregular mineralization of shattered or permeable rocks. The lodes are usually simple veins occupying fault fissures. The important ore bodies are those in the limestone. These are usually rudely lenticular in shape, and lie roughly parallel to the bedding of the rock occurring scattered irregularly through it. They are usually either in a prom-

inent fault fissure or closely connected with one. Ores of the third class have also contributed largely to the total output.

The ores were undoubtedly originally sulphides deposited by ascending solutions. The igneous rocks of the district probably have had an intimate influence on their formation by supplying material together with heat and chemical activity to the underground waters.

The report closes with a detailed description of some of the more important mines, including maps and sections of the workings. W. E. F.

No. 16.—The Carboniferous Formations and Faunas of Colorado; by GEORGE H. GIRTY. 546 pp., 10 pls. The first 216 pages of this work are devoted to a useful review of the literature and discussion of the interpretations of the geology and paleontology of the Colorado region given by previous writers. In the second part, pp. 217–267, the author discusses the faunal evidence and correlations furnished by the material under investigation; and in the remainder of the volumes (pp. 268–546) the species are described and figured.

The result of study of the collection shows the presence of both Mississippian and Pennsylvanian faunas.

The Mississippian fauna occurs in the Leadville limestone and its equivalents, the Ouray and the Millsap limestones. These are interpreted as equivalent to the Kinderhook and lower Burlington faunas of the Mississippi valley region.

To the Pennsylvanian are referred the Hermosa, Weber, Maroon, Robinson, Molas, and Rico formations. Essentially the same fauna is reported from the Hermosa, Weber, Lower Maroon of the Crested Butte section, and from the Weber shales and grits of the Leadville section. This fauna is considered by the author to be older than any of the Pennsylvanian beds of the Kansas and Nebraska sections. The Rico formation is by its fauna interpreted as probably of about the horizon of the Deer Creek, Hartford and Howard formations of Kansas. H. S. W.

No. 17. Geology and Water Resources of Nebraska West of the One Hundred and Third Meridian; by N. H. DARTON. 66 pp., 43 pls., 23 figs. With a few minor changes this paper is a reprint of pp. 719–785 in the Nineteenth Annual Report.

No. 19.—Contributions to the Geology of Washington. 98 pp., 20 pls., 3 figs. This publication contains two papers: Geology and Physiography of Central Washington; by GEORGE OTIS SMITH, and Physiography and Deformation of the Wenatchee-Chelan District, Cascade Range; by BAILEY WILLIS. During Pliocene time a lowland surface was developed in Central Washington and the ancient controlling drainage system may possibly be indicated. This plain was uplifted and warped so that the Cascade range is complex in type. Geologic processes worked rapidly in this region, as is shown by the Eocene section of 10,000 feet divisible into four distinct formations, separable both by physical breaks and differences in fossil flora. The unique char-

acter of this region is the modification of the peneplain by warping so as to form anticlinal ridges and synclinal valleys. In the Wenatchee-Chelan district glaciation furnishes an additional datum plane and Mr. Willis has worked out the physiography in great detail. He recognizes five physiographic stages from the Pliocene to the Recent, inclusive. As a study of physiographic method and of criteria for recognizing peneplains this paper is a valuable addition to geologic literature.

2. *Alaska, Glaciers and Glaciation;* by G. K. GILBERT, being Vol. III of the Harriman Alaska Expedition reports, published with coöperation of the Washington Academy of Sciences. New York, 1904. (Doubleday, Page & Co.) 231 pp., 18 maps and plates, 106 figs.—This most instructive and suggestive report may be briefly reviewed under four headings: preglacial land forms, erosion by Pleistocene glaciers, existing glaciers, and glacial erosion in general. A noteworthy feature of the preglacial topography was the occurrence of mountain ranges formed by the broad uplift and dissection of extensive peneplains, which, it may be here noted, are but so many additional instances of the difficulty into which Suess's hypothesis of the origin of horsts must lead the geologist. These peneplains and the neighboring ocean were once at (almost) the same level: according to Suess' hypothesis, the peneplains have become horsts, not by local elevation, but by the depression of the surrounding surfaces; and in this case, as in many others where horsts have ancient peneplains for their uplands, it is evident that such an explanation involves the depression of all the oceans of the world, and the continents along with them, the horsts alone standing still. This is of course conceivable, but it is an extravagant conception. Certain parts of the coast show lowlands of denudation adjacent to the mountains, thus recalling the coast plain of Norway as described by Reusch. Gilbert explains the Alaskan coast plain by general erosion when the land had gained something like its present altitude, and does not explicitly call upon marine erosion, as Reusch did for the Norwegian example. Erosion of valleys to a greater depth during a time of greater elevation is also inferred, but hardly proved, unless it is held that glacial erosion cannot have scoured out the channels now occupied by the sea while the land held its present position.

Gannett's thesis that a glaciated valley is comparable with a river channel is supported by a great variety of facts. Cirques and hanging valleys characterize the coastal mountains: repeated examples are figured and described. In this connection reference may be well made to the Chief Mountain (Montana) map sheet, lately issued by the U. S. Geological Survey, an elegant example of fine topographic work by Messrs. Matthes and Sargent, in which cirques and hanging valleys are remarkably well portrayed. Indeed so numerous are the examples of these forms in once-glaciated mountains in many parts of the world that the occasional occurrence of imitative forms in non-glaciated districts can

hardly be used, as they lately have been by Russell (Science, May 20, 1904, 785), to throw doubt on the glacial origin of normal cirques and hanging valleys. It may be difficult to explain the imitative forms, but as the matter now stands, it is their explanation that is deficient, and not the explanation of the normal forms by glacial erosion as stated by Gannett and Gilbert. True, the trunk valleys are often so much deeper than the hanging lateral valleys as to make it very difficult indeed to ascribe their excess of depth to glacial erosion ; yet the hesitation that one may feel here is more likely to be based on a conservative habit of thought than on direct argument ; for the valleys are certainly valleys of erosion, and when it is once shown that glaciers are effective erosive agents, it does not appear more unreasonable to ascribe the great trough valleys to the work of frozen water than to that of molten water. It is pointed out by Gilbert that the main valley sides are relatively smooth and trough-like, sometimes exhibiting details of form that suggest the action of an eroding agent which moved in nearly horizontal lines, and thus contrasting strongly with the ravined valley sides of non-glaciated mountains, where the agent of erosion has manifestly worked on down-slope lines. The extension of these main valleys across the coast plain leads to the conclusion that their erosion was accomplished by the larger glacial streams in consequence of their relatively great velocity ; thus agreeing with the opinion reached by Richter for the over-deepened valleys of the Alps.

The existing glaciers are described and illustrated in much detail, with especial reference to their recent variations. It is shown by a careful comparison of all available descriptions, maps and photographs, that the changes of the glaciers have been singularly discordant during the past century, and the discordance is held to be too great to be explained by lagging. A most ingenious suggestion is then made that under certain changes of mean temperature, one set of glaciers might be caused to advance while others near by would be compelled to retreat. Glacial students who visit Alaska during the present century thus have a pleasing problem set before them for solution.

The volume closes with some general conclusions as to glaciers, in which we find an altogether new view as to the possibilities of glacial erosion beneath the sea. It has been recognized in recent years that the invasion of once-glaciated valleys by the sea was not, as it has usually been regarded, an evidence of submergence, for heavy glaciers can certainly erode beneath sea level. Gilbert now gives reasons for thinking that heavy tidal glaciers are not effectively buoyed up by the water that they enter, and that they erode beneath sea level about as effectively as on a land surface. If this should be fully demonstrated, it would lead to a radical change of opinion regarding the changes of level indicated by fiord coasts. "Plucking" is looked upon as of great importance in glacial erosion. W. M. D.

3. *The Origin and Relationship of the large Mammals of North America and the Caribou;* by MADISON GRANT, Secretary of the New York Zoological Society.—These articles, reprints from the annual (eighth and seventh) reports of the New York Zoological Society, form an exceedingly interesting volume of about 60 pages, copiously illustrated by 32 exceptionally fine plates, reproductions of photographs of the caribou in their native haunts, in captivity in the N. Y. Z. park, and of mounted specimens in the American Museum. A map showing the distribution of the two kinds in North America is also given. The purpose of the first article, as stated by the author, is "to briefly review the living large mammals of the United States and Canada, and to endeavor to trace their past history," such an analysis being possible because of the increase in knowledge of the true relationship of mammals and their geographical distribution greatly aided by the definite proofs given in recent paleontology. The facts are very clearly presented in concise divisions showing the existence of two definite continental radiations, proved by distinct faunal groupings showing geographical origin and connection, followed by a discussion of the various distinct groups of animals themselves with a table showing their derivation, concluded by a summary of previously mentioned facts. In the second article, the facts correlated in regard to the caribou are presented in a similarly clear manner, showing the origin of the name, classification of the various species with their geographical origin and distribution. K. J. B.

4. *The Mammals of Pennsylvania and New Jersey;* by SAMUEL N. RHODES.—This volume (privately published) of 266 pages with 9 plates (reproductions of photographs) and faunal map is, as shown by the title page, a "biographic, historic, and descriptive account of the furred animals of land and sea, both living and extinct, known to have existed in the states of Pennsylvania and New Jersey" and is "designed as both a popular and scientific presentation of a branch of nature-study hitherto unduly neglected." Among the many valuable facts given in the introduction, one of especial interest is that "the list of fossil mammalia found in these two states far exceeds that of the rest of the United States east of the Mississippi river." This is due to the researches of Leidy, Cope, and Marsh among the fossil-bearing limestone caves and fissures in the Delaware valley and in the marl beds of New Jersey. Above 90 species are cited of which 30 are found still existing; these, with over 70 living species and 25 sub-species or geographic races, show not only a surprisingly large mammalian fauna, but also the noteworthy fact that the fossil fauna exceeds that of the living. The vast amount of careful labor expended in compiling this valuable work will be appreciated by all students, and writers on kindred subjects. K. J. B.

5. *Medusæ of the Bahamas;* by ALFRED GOLDSBOROUGH MAYER. Memoirs of Natural Science, vol. I, No. 1, of the Museum of the Brooklyn Institute of Arts and Sciences.—This article of 33 pages, with 7 heliotype plates, is based on observations

made by the author during June and July, 1903. Of the 43 species found, 5 are known only from the Bahamas, 2 of which are locally abundant. Among them, one genus (*Paranemus*) and two species are new to science. The opportunity of studying asexual budding was afforded by a most interesting example of *Eucheilota paradoxica*. The paucity of the medusa-fauna of this locality compared with that of Tortugas, Florida, is given as being largely due to local conditions. The former being situated to the windward, while the latter is to the leeward of the Gulf Stream, is depleted by the prevailing winds, and is poor in those creatures which are mainly dependent upon great currents for their distribution. K. J. B.

II. Miscellaneous Scientific Intelligence.

1. *International Congress of Arts and Science at the Universal Exposition, St. Louis.*—An International Scientific Congress will be held at St. Louis from Sept. 19–25, in connection with the Universal Exposition. Professor Simon Newcomb is the President of the Congress and Professors Hugo Muensterberg and A. W. Small the Vice Presidents. The whole field of knowledge is divided for the purposes of the Congress into seven divisions, these further into twenty-four departments and these finally into some 128 sections. The official program contains the following statements:

"After the opening of the Congress on Monday afternoon, September 19, will follow, on Tuesday forenoon, addresses on main divisions of science and its applications, the general theme being the unification of each of the fields treated. These will be followed by two addresses on each of the twenty-four great departments of knowledge. The theme of one address in each case will be the Fundamental Conceptions and Methods, while the other will set forth the progress during the last century. The preceding addresses will be delivered by Americans, making the work of the first two days the contribution of American scholars. On the third day, with the opening of the sections, the international work will begin. About 128 sectional meetings will be held on the four remaining days of the Congress, at each of which two papers will be read, the theme of one being suggested by the Relations of the special branch treated to other branches; the other by its Present Problems."

The list of distinguished scholars, from Europe and America, announced as speakers at the Congress, ensures it an eminent degree of success in its grand object of "the unification of knowledge."

2. *Geographen Kalender, 1904–1905*, edited by Hermann Haack; 290 pp., 16 maps: Gotha (Justus Perthes).—There is no one publication which serves so well the purpose of an annual reference book of geographical matter as Dr. Haack's "Kalender." New explorations, adjustments of boundaries, development of canals, railroads, etc., are described and mapped. To this are added a list of addresses of scientists and societies, a review of the year's geographical literature and a mass of useful statistics.

OBITUARY.

JOHN BELL HATCHER, Curator of Vertebrate Paleontology in the Carnegie Museum at Pittsburgh, died of typhoid fever at Pittsburgh on July 3, 1904. By his death Paleontology has lost an investigator and writer of unusual ability, a man who had few equals in his chosen line of research.

Born at Cooper, Green County, Iowa, October 11, 1861, his early years were passed among surroundings and under conditions which developed a character of absolute integrity and of rare self-reliance and determination. He entered the Sheffield Scientific School of Yale University in his twentieth year, when he improved to the utmost the educational facilities offered to him. Although a few weeks before the graduation of his class, in 1884, he expressed himself as being still uncertain in his choice of future occupation, it is on record that during his college course he gave especial attention to those studies in Natural History which fitted him for his life's work. Probably Hatcher's marked ability had already become known to the late Professor O. C. Marsh of the Yale University Museum, who secured his services as field collector. Hardly waiting until the close of his graduation exercises, he left New Haven on June 25, 1884, for the West, where he collected in Kansas and Nebraska for about a month, under the direction of Charles H. Sternberg. Later he commenced work by himself, and remained in the field alone until the approach of winter, when he returned to New Haven. When not in the field, much of Hatcher's time was spent in preparing and studying the fossils he had collected, and in making himself generally familiar with them as an aid to further collecting. He also pursued advanced studies in Botany with the late Professor D. C. Eaton, who became sincerely attached to the young scientific worker, and who always expressed the highest regard for his character and ability. In 1885, after collecting Permian fossils in Texas, Hatcher returned to Kansas and continued his work in the Pliocene formations. The seasons of 1886 and 1887, which were spent in the Bad Lands of Dakota and Nebraska, won him renown as a collector. From the famous "Brontotherium Beds," he shipped to the East carload after carload of fossils, including the bones upon which Marsh founded his genera *Brontotherium* and *Protoceras*. In fact, Hatcher's labors in the field were of inestimable value, and the collections made by him, more than those of any other of his scientific assistants, furnished to Professor Marsh the material for his paleontological work.

By this time, Hatcher's services had become so valuable that Marsh kept him constantly in the field. The winter months were spent in Maryland, Virginia and North Carolina. The variegated red and gray clays conspicuous between Baltimore and Washington had long been a puzzle to geologists. Many collectors had visited the outcroppings, but had failed to obtain characteristic fossils at the typical localities. Hatcher, whose

keen eyes were fresh from the western fossil beds, was entrusted with the work. In two months he brought together a collection in which were abundant dinosaurian remains associated with the bones of other reptilian orders.

The summers of 1889 to 1892 were spent in Converse County, Wyoming, where Hatcher obtained a magnificent collection of Ceratopsia material. One of the best known types of this group is Marsh's *Triceratops*, now exhibited in the Yale University Museum. Another notable dinosaur collected by Hatcher is the *Claosaurus*, mounted at Yale by Professor Beecher after Marsh's death. When the latter retired from his position of Vertebrate Paleontologist of the United States Geological Survey, in 1892, funds were no longer available for collecting on so extensive a scale, and Hatcher severed his connection with the Yale Museum. Shortly after, he became Curator of Vertebrate Paleontology and Assistant in Geology at Princeton University. His work during the following years won him the highest praise. In spite of great hardships, he successfully made collecting and exploring expeditions into the wilds of Patagonia. Neither ill health nor accidents, such as the loss of his saddle and pack animals hundreds of miles from any source of supplies, could daunt him, and his work in the southern continent proved not only of the highest value to the naturalist and paleontologist, but his chronicle of these expeditions is also of great interest to the general reader.

In 1900 he accepted the Curatorship of Vertebrate Paleontology in the Carnegie Museum at Pittsburgh, which position he filled with honor to himself and to the great improvement of his department. Engaged by the United States Geological Survey to continue Professor Marsh's work on the Ceratopsia, he had nearly finished that difficult task, involving a careful study of the material at Yale and at the National Museum, which he had himself collected years before. His talent and industry had already won him an enviable position among paleontologists, and he had just accepted the Curatorship of Vertebrate Paleontology in the United States National Museum, when his untimely death occurred.

Hatcher's reputation as a paleontologist rests mainly on his work upon the fossil Reptilia, his principal contributions appearing in the Memoirs of the Carnegie Museum, under the titles of "Diplodocus Marsh," and "Osteology of Haplocanthosaurus." His valuable treatise entitled "Oligocene Canidæ" was published in the same form. Latterly Hatcher developed considerable talent as a stratigrapher, as is shown by his memoir on *Haplocanthosaurus*, the records of the Patagonia Expeditions, and by other shorter publications, which is the more remarkable inasmuch as many able paleontologists have shown little skill in this branch of geology.

Of marked avidity for the hardest work, and of quick and accurate discrimination in his scientific labors, Hatcher accomplished much during his short career. His constant loyalty and thoughtful kindness endeared him to those who were so fortunate as to enjoy his intimate friendship. GEORGE F. EATON.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXI.—*The Velocity of the Propagation of Magnetism*; by HENRY A. PERKINS.

THE effect of self-induction in a circuit causing a retardation in the establishment of a magnetic flux is of course well known to everyone; but an allied effect, caused not by the inductance between coil and magnetic circuit, but in the magnetic circuit itself, thus causing a very perceptible interval of time between the appearance of the magnetism at two points, has not been so thoroughly studied, although it must be present in all alternating current machinery to a certain degree. This retardation is thus due to the eddy currents in the core of the magnet in question and is a complicated function of the various physical properties of the core, the frequency and magnitude of the impressed electromotive force.

This phenomenon was first investigated in detail by Oberbech* in 1884. His apparatus consisted in a core with magnetizing coil. Beside this coil were two others whose distance apart could be varied at will. To measure the phase angle between the electromotive force generated in these coils when a sinusoidal e.m.f. was impressed on the main coil, he made use of a dynamometer, the fixed coil being in series with one of the sliding coils, and the movable one with the other. The resulting deflection he showed to be a function of various known quantities and some unknowns that were eliminated by repeating the experiment with added resistance in series with one of the two circuits, thus obtaining a different deflection. This was repeated at different distances up to 20^{cm}. His results show values of the lagging angle from 2° 16′, when the distance was

* Wied. Ann., xxii, p. 73.

10^{cm} and the core a bundle of 64 small steel wires, up to 96° 12′ in 10^{cm} for a steel bar of $1{\cdot}2^{cm}$ diameter. This shows at least qualitatively what we should expect, that lamination reduces the lag. The curves of flux intensity taken along the bar appeared to be logarithmic curves whose equation was $Q = Q_0 e^{-\beta x}$. β varied somewhat, and his results were tabulated as follows:

$$\beta \text{ for soft iron } = \begin{cases} 10{\cdot}27 \\ 10{\cdot}17 \\ 10{\cdot}07 \end{cases}$$

$$\beta \text{ for hard iron } = \begin{cases} 14{\cdot}8 \end{cases}$$

$$\beta \text{ for steel } = \begin{cases} 14{\cdot}51 \\ 16{\cdot}16 \\ 16{\cdot}37 \end{cases}$$

x being measured in meters. In conclusion, the author says that the size of β varies only as the material and is independent of the diameter. This is also true of direct current phenomena; hence he argues that were it not for the opposition of eddy currents the velocity would be enormous.

When I first began investigations on this effect I was not aware of the work just cited. But inasmuch as the results were somewhat of a qualitative nature, and the method used is open to serious objection, I thought it worth while to continue the research.

The method employed was in some respects similar to that of Oberbech. A magnetizing coil was mounted on the center of a steel bar about one meter long and having a section of $2{\cdot}83^{cm^2}$. It was of the best English tool steel. This material was used in order to obtain as low a velocity as possible and thus measure it more readily. On the middle of the magnetizing coil were wound 250 turns of fine wire, and sliding on the core were two more coils, one of 500 turns and one of several thousand. As will be seen, the exact number is not an essential quantity.

In performing the experiment one of the movable coils was set at some known distance from the exciting coil at the center, and the angle of lag between it and the small coil of 250 turns was measured. For short distances, up to about 8^{cm}, one of 500 turns was used; beyond that the larger coil. The instrument by which this angle was measured was a small quadrant electrometer having double quadrants and an aluminum needle suspended by a quartz fiber and dipping into sulphuric acid through which the contact was made. The needle and one pair of quadrants constituted one terminal and the other pair of

quadrants the other. By means of two Kempke discharge keys the circuits were so arranged that the electrometer was normally on short circuit, but on pressing the keys simultaneously the terminals of the external circuit were simultaneously attached to the electrometer terminals. This method was essential, for with one terminal free and the other connected to some metal object the instrument would be most violently deflected; hence the necessity for making the contacts exactly together.

As it was purposed to measure alternating voltages, the instrument was calibrated with the use of alternating e.m.f. of the

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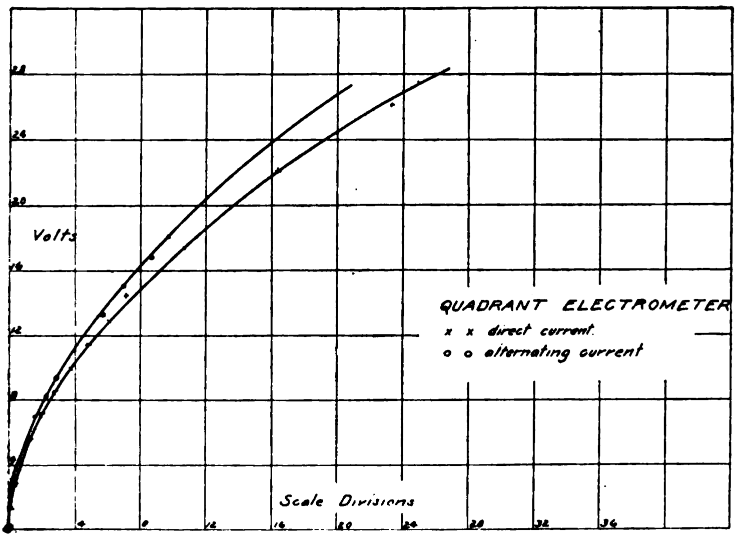


same frequency. These were measured by "weighing" in a Kelvin balance the current that went through a non-inductive resistance across whose terminals the electrometer was connected. The resistance was measured after each reading to allow for possible changes due to heating. It may be of interest to note that the calibration curve as obtained by this method differed considerably from one obtained with constant voltages. This was doubtless due to the capacity introduced by the cup of sulphuric acid into which the needle dipped.

Several readings were necessary in determining a single angle. Calling the small central coil wound on the exciter "A," and the more distant coil "B," we may simplify the description as follows: The electrometer was first connected to A, giving a deflection D_a which corresponded to an induced potential V_a.

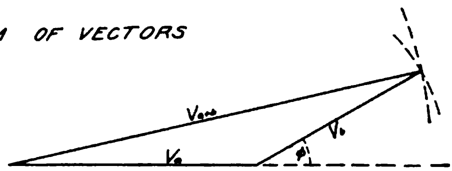
Next by connecting to B, D_b and thus V_b was obtained. Then by connecting A and B in series in such a way that they were in accord, V_{a+b}, and finally when opposed $V_{a'-b}$, were observed. The accent above "a" in the last quantity refers to the necessity of reversing the connections of A (or B), and, strangely enough, the deflection given by any coil was slightly altered on reversal. The reason for this I was unable to determine, unless, indeed, it is due to inequalities between the positive and negative loops of the commercial current which was used. This seems unlikely, and I purpose to investigate the matter further. This effect was not harmful if properly observed and allowed for.

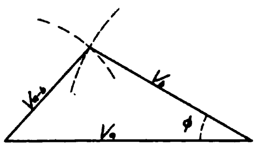
With the four readings just referred to it was possible to calculate the angle of lag in two ways that can best be seen in graphic form.

If the two vectors V_a and V_b were in phase, then V_{a+b} must be equal to their arithmetical sum, otherwise it will be less, and

2

DIAGRAM OF VECTORS

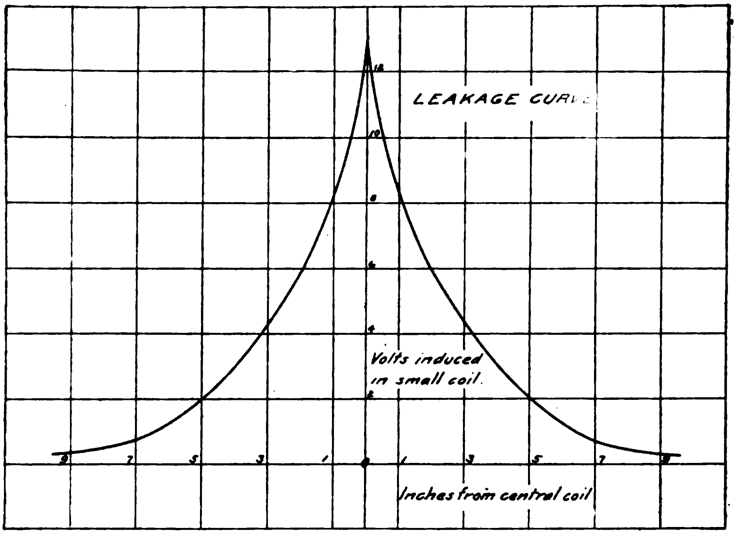




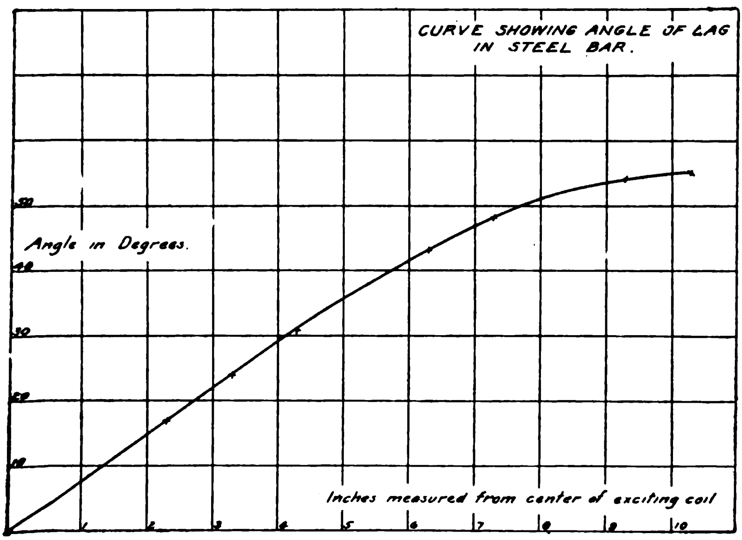
this was always found to be the case. The construction can be seen from a glance at the diagram, which gives us ϕ, or the angle of lag. Similarly with the two coils opposed, $V_{a'-b}$ will be greater than the arithmetical difference of $V_{a'}$ and V_b, as shown above. In the results recorded here the latter method was used as being less liable to error, for it involved no large deflection like D_{a+b} and for small values of ϕ it is also true from trigonometrical reasons.

Determinations of ϕ were made at intervals up to nine inches from the central coil, and from these values the velocities for the parts in question were calculated. From inspection of the curve it is clear that $\frac{d\phi}{dx}$ is not a constant, hence the velocity cannot be constant. The velocity at any point in the bar was found from the angle curve by observing the change in lag for a short distance on either side of the point in question. Calling

3


LEAKAGE CURVE
Volts induced in small coil.
Inches from central coil

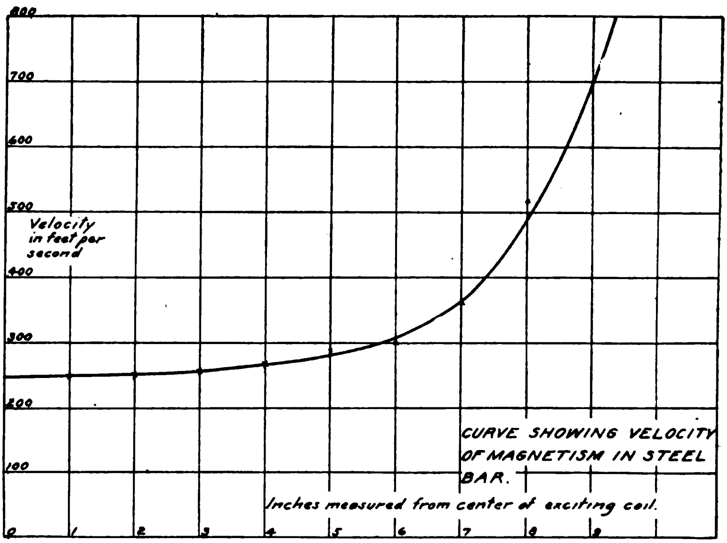
4


CURVE SHOWING ANGLE OF LAG IN STEEL BAR.
Angle in Degrees.
Inches measured from center of exciting coil

this distance "d" and the angular difference "δ," we have $v = \frac{360 \cdot d \cdot n}{\delta}$, where $n =$ the frequency, and in this case was 60 cycles per second.

In comparing the curves of magnetic leakage and velocity it is evident that as the flux in the bar diminishes the velocity increases with a consequent lessening of the lag per unit length. This is what would be expected, for with a decrease of flux the eddy currents must grow smaller, and there is less opposition to the advance of the magnetism. Beyond nine inches the velocity

5



increases with great rapidity and presumably becomes equal to the velocity of light when the flux density is infinitely small, or when the core is a non-conductor. To test this latter case I made an observation with an air core, and with coils A and B about 6 inches apart. In this case the induced e.m.f. was too small to appreciably affect the electrometer, so a very sensitive D'Arsonval ballistic galvanometer was used. Instead of an alternating current a constant voltage was impressed on the exciting coil and the throw of the galvanometer observed at both "make" and "break." Now if B is so adjusted that it gives exactly the same throw as A, then when they are in series and opposed there should be no throw provided the resistance and self-induction of both are made equal. This condition was fulfilled by adding an external coil in series with A, thus mak-

ing that circuit similar to that of B. The result, as expected, was no deflection, although so sensitive was the apparatus that a change of one millimeter in the position of B overthrew the equilibrium. This at least showed that the velocity must be exceedingly great as compared to that in the steel bar.

It only remains to show that the mathematical theory predicts results similar to that observed. In an article by J. Zennech,* the author develops the theory of the propagation of magnetism, which, though it takes no account of hysteresis, should give at least approximate values when properly used. The fundamental equation is similar to that for variable currents:

$$\text{(1)} \qquad Qw_m = -\frac{\delta V_m}{\delta x} - p_m\frac{\delta Q}{\delta t},$$

where Q = flux,
w_m = reluctance,
V_m = magnetic potential,
p_m = coefficient of self-induction of the core.

By applying the law that the rate of leakage is proportional to V_m, i. e.

$$\text{(2)} \qquad C_m = -\frac{\delta Q}{\delta x}\Big/ V_x,$$

where C_m is the magnetic analogue of capacity, and combining (1) and (2), the equation (3) is obtained:

$$\text{(3)} \qquad C_m p_m\frac{\delta Q}{\delta t} + C_m w_m Q = \frac{\delta^2 Q}{\delta x^2},$$

whose solution must be of the form:

$$\text{(4)} \qquad Q = Q_o e^{-\beta x} \cdot e^{i(\pi nt - \gamma x)},$$

where β is the damping factor, n = twice the frequency and $\gamma = \frac{\pi n}{v}$, v being the desired velocity. This solution satisfies the equation when

$$\begin{matrix}\text{(5)} \\ \text{(6)}\end{matrix} \qquad \begin{cases}\beta^2 - \gamma^2 = C_m \cdot w_m \\ \text{and } 2\beta\gamma = C_m \cdot \pi n p_m.\end{cases}$$

To find v it is necessary to know three of the quantities, β, C_m, w_m and p_m. As p_m presents the greatest difficulty, the first three were selected by the author of this article. β was deter-

* Drude's Ann., 1903, No. 4, p. 845.

mined directly from the leakage curve, assuming it to be fairly well represented by the equation $\beta = \log \frac{Q_o}{Q_x} / x$. The average value was ·16, which gives a curve fitting the original fairly well near its middle point. This agrees quite closely with Oberbech's value for steel; the difference in the position of the decimal point is due to his choice of the meter as the unit of length instead of the centimeter.

The calculation of C_m is more difficult, particularly as Dr. Zennech is not quite explicit in explaining V_x; but I venture to suggest the following method as applied to a point four inches from the center of the exciting coil. The difference of potential of the two faces of a coil of n turns carrying a current I is $\frac{4\pi n I}{10}$ as determined by the amount of work done in carrying a unit pole from one face around outside the coil to the other. This work would be increased if the medium were of greater permeability than air; moreover, the work done would be half the total if the unit pole were carried only from one face to the far end of the bar, where the flux is almost zero. The fall of potential would then vary as Q along the bar. From these considerations I calculated V_x by the following equation:

$$V_x = \frac{4\pi n I}{10} \cdot \mu \cdot \frac{Q_x}{2Q_o} = 27,$$

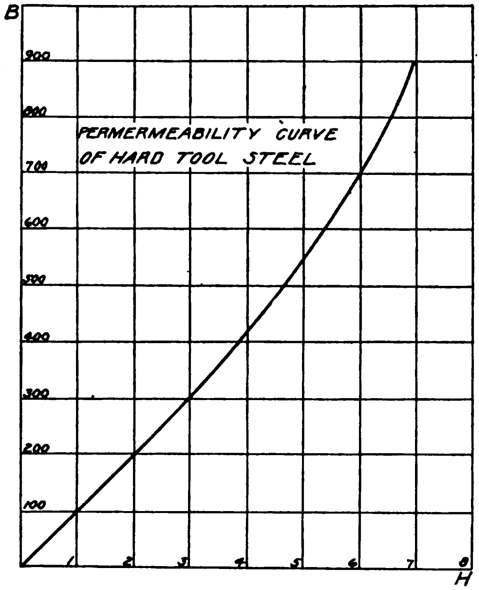
where $n = 4077$ (No. turns in coil),
$I = {\cdot}015$ ampères,
$\mu = 2{\cdot}95$,
and $\frac{Q_x}{Q_o} = \frac{3{\cdot}1}{12{\cdot}9}$, as may be seen from the leakage curve.* The value of μ was found by carefully measuring the resistance of the exciting coil and the currents flowing in it under an alternating pressure of 120 volts, when the steel core and an air core were successively used. The impedance in one case was 7998 ohms, in the other 2727. Knowing the resistance and the frequency, it was easy to calculate the coefficient of self-induction for iron (L_i) and for air (L_a), and $\mu = \frac{L_i}{L_a}$.

Referring to equation (2) we still have $\frac{\delta Q}{\delta x}$ to determine, which can be done readily by differentiating $Q = Q_o e^{-\beta x}$ and substituting the values of Q_o, β and x. β has been determined, $x =$

* These and other values were taken from the original curves as plotted in the laboratory. Those prepared for photographic reproduction give the general form correctly but are not strictly accurate copies.

$10{\cdot}16^{cm}$, and Q_o is found from the equation $Q_o = \dfrac{10^8\sqrt{2}E \cdot 2}{\pi n w}$, where $E = 12{\cdot}9$, $n = 500$, $w = 377$, and Q_o is the average value of the flux at the center of the exciting coil. Hence $\dfrac{\delta Q}{\delta x} = -Q_o\beta e^{-\beta x} = -\dfrac{6146 \times {\cdot}16}{e^{1{\cdot}63}} = 193$. Finally $C_m = -\dfrac{\delta Q}{\delta x}\Big/V_x = \dfrac{193}{27}$, the negative sign vanishing because $\dfrac{\delta Q}{\delta x}$ is negative.

6



The average flux density at a point four inches from the center is 522 lines per square centimeter, obtained similarly to Q_o above, and the permeability at this density was found to be 110, as shown in the permeability curve of the bar used.* This gives the reluctance per unit length as $w_m = \dfrac{1}{110 \times 2{\cdot}83}$; 2·83 being the cross section of the bar.

We are now in a position to make the final calculation, employing equation (5) and solving it for γ, which is equal to $\sqrt{\beta^2 - C_m w_m}$. We have $\gamma = {\cdot}0513$ and $v = \dfrac{\pi n}{\gamma} = 7336^{cm}/_{sec}$ or

* The author owes sincere thanks to Messrs. E. E. Moran and D. H. Miller, students in Yale University, for the determination of the BH curve of the steel bar.

$245^{ft}/_{sec}$ as against $257^{ft}/_{sec}$ actually observed. It must be admitted that values of v calculated for other points along the bar did not agree so closely with observation, those nearer the center being too small and those farther out too large; but considering the fact that equation (5) makes γ exceedingly sensitive to very small errors in the values β, C and w, a closer agreement could hardly be expected.

A more approximate method suggested by Zennech gives $^{\beta}/_{\gamma} = 2{\cdot}4$ for cases of moderate permeability and frequencies of about fifty cycles. Using $\beta = {\cdot}16$ this gives $v = 5712^{cm}/_{sec}$, which is as close as could be expected from the approximate nature of the assumptions.

In conclusion we may, I think, accept as proved that the velocity of magnetism in metallic paths, and especially those of high permeability, is small compared to that in non-conducting bodies. That this effect is due to eddy currents and therefore variable, diminishing as the flux diminishes along the bar. That this velocity is not a simple function of x, but depends on the physical properties of the bar, such as ohmic resistance and permeability, as well as the magnetic density at the point in question. And that this retardation is great enough to cause a very perceptible lag where the density is high and the lamination poor; great enough indeed, it would seem, to call for recognition in the design of many forms of electromagnetic machinery.

Trinity College, July, 1904.

ART. XXII.—*The Geomorphic Origin and Development of the Raised Shore Lines of the St. Lawrence Valley and Great Lakes;* by R. CHALMERS, LL.D., of the Geological Survey of Canada.

[Published by permission of the Acting Director of the Geological Survey.]

IN a paper published by the writer in 1896 on the "Pleistocene Marine Shore Lines on the South Side of the St. Lawrence Valley,"* and in an official report issued in 1897,† it was shown that the valley referred to and the region of the Great Lakes must have stood at a lower level at the close of the Pleistocene‡ than at the present day, the movements of the ice in the glacial period and the existing altitudes of the shore lines clearly proving this. Investigations regarding the position and elevation of the shore lines of the St. Lawrence basin have been continued at intervals since and considerable new data obtained. Very interesting observations have been made on the north side of the two lower great lakes, Ontario and Erie, showing the geomorphism which the region has undergone in the post-glacial or recent stages of the Post-Tertiary. The following notes, deduced from the field work of the last seven years, are preliminary to a more detailed discussion of the results.

High-level shore lines of marine origin fronting the St. Lawrence to the north have been traced almost without interruption from the Gulf of St. Lawrence westward along the northern base of the Notre Dame Mountains, a distance of 550 miles or more, the altitude of the highest at Gaspe being 240 feet, while as we approach the international boundary east of Lake Champlain it is 865 feet. Another series extends along the north side of the St. Lawrence and Ottawa rivers at approximately the same altitude, reaching 900 feet north of the city of Ottawa. Besides the regional upheaval indicated by the shore lines observed on both sides of the valley, differential vertical movements of a local character have taken place at intervals along these strands since they were at sea level, or in a horizontal attitude; in some places there appears to have been a greater uplift than in others, and such uplift seems occasionally to have been followed by still more local downward movements. On the south side of the valley and in the maritime districts wherever the shore lines rest upon crystalline, or igneous rocks, they were observed to be deformed to a greater extent than elsewhere and raised above the average height. This singular and

* This Journal, April, 1896, vol. i (4th series), pp. 302–308.
† Annual report, Geol. Surv. Can., vol. x, 1897 (new series), pp. 12–54 J.
‡ The term Pleistocene embraces the period beginning with the Post-Tertiary and ending with the Champlain, or with the deposition of the Leda clay and Saxicava sand.

apparently abnormal feature is more particularly noticeable in that portion of the highest shore line which extends along the south side of the valley referred to for a distance of 100 to 120 miles east of the international boundary, where it rests on the northwest flank of the Sutton or Green Mountain range in its extension into Canada. Similar deformations were also observed on the north side of the St. Lawrence and Ottawa valleys, more especially of the latter. On both sides of the St. Lawrence marine plain, however, the shore lines become considerably broken up before approaching the Archean rocks to the west.

In the region of the Great Lakes high-level shore lines were observed and described many years ago by Logan, Chapman, Fleming, R. Bell, Spencer and others, while more recently Lawson and Bell have explored and traced them along the north and northwest side of Lake Superior, where they bounded a great body of water to which the name Lake Warren was given. On the north side of Lakes Erie and Ontario four or more of the strands referred to occur. The lowest, which has been named the "Iroquois beach" by Spencer, and was first traced by him, is not horizontal, but has an average descent southwestward of about two feet to a mile. It extends from the Trent river, or from a point north of Belleville, to the head of Lake Ontario. Another lies above it having a similar slope, not however much more than about a foot to the mile, the altitude falling from 775 feet at Myrtle, Grand Trunk railway, to 705 feet in Lambton county. This is probably a part of the so-called Algonquin shore line, which has been traced on the south side of Georgian Bay with such care and described by Mr. A. F. Hunter of Barrie*. The third is a well-defined one which was followed from Trent river to Hyde Park, Middlesex county, a distance of about 200 miles, and is practically horizontal throughout. The altitude is 890–892 feet. The fourth and highest is terrace-like, and may be called a plateau, as it is 1100 feet high in its eastern extension in Durham county, near Pontypool, and 1200 feet near Stratford, Perth county. A depression crosses it east of the Credit river.†

These four Ontario shore lines are of lacustrine origin; but how the waters of the Great Lakes were held up to their level is the great problem. As stated in the opening sentences of this paper, there seems no doubt that the whole of the region of the Great Lakes stood at a lower level than at the present day during the existence of the earliest and largest of these bodies of water—Lake Warren,—that is, at the period when the shore lines now found at an altitude of 1100–1200 feet were

*Summary Report, Geol. Surv. Can. for 1902, pp. 279–302.

†The altitudes were all measured from railway stations and referred to mean sea level. See Summary Report, Geol. Surv. Can., 1902, pp. 272–274.

formed. A great mass of literature bearing on the origin and development of these old water lines and of the lake basins themselves has appeared from time to time in the scientific journals during the last two or three decades, and geologists are by no means in accord as to their origin. In the United States the hypothesis of an ice dam in the St. Lawrence Valley during the latter part of the glacial period is generally accepted, but most of the Canadian geologists are inclined to regard that of an oscillating land barrier to the north and northeast of the Great Lakes as the most probable cause.

In regard to the latter theory it may be stated that there is a belt of granite or Archean rocks about fifty miles wide crossing the St. Lawrence at the Thousand Islands connected with the Adirondacks to the south, and with the great Archean area to the northwest, towards which it widens out as we proceed in that direction. This Archæan neck, as it is sometimes called, seems to have been an oscillating axis in the Post-Tertiary period and up to the present day. As, however, the shore lines of the St. Lawrence Valley and Great Lakes are of post-glacial age, it is only its later Pleistocene and recent history with which we are concerned. At this stage the St. Lawrence Valley below the Thousand Islands and the region of the Great Lakes would be at a lower level than at present, as already stated, and the axis referred to must have been higher. This valley would then be a gulf or arm of the larger Gulf of St. Lawrence and the barrier described would form, on its east side, the shore of the Champlain sea, and on its west a great fresh-water lake, or series of lakes, would be held in, the floor of which is now represented to some extent in Southwestern Ontario by plains and terraces 1100–1200 feet above the sea. These water levels, as already pointed out, can be seen at Stratford and on the watershed between Ontario and Simcoe Lakes, also at corresponding heights in the Lake Superior basin, as described by Bell and Lawson.*

The sequence of events which occurred in the St. Lawrence Valley and basin of the Great Lakes brought about by the changes of level which followed may be thus summarized:—

1. A subsidence of the Archean rocks immediately to the north of the Great Lakes with correlative upward movements to the east and to the west. These changes of level seem to have reached a stationary position, temporarily, when in the lake region the 890–892 feet shore line was formed; and in the St. Lawrence Valley, the 890–895 feet terrace.

2. Another subsidence of the axis referred to then followed,

* The Geological History of Lake Superior; Trans. Can. Institute, Memorial volume, 1849–99, by Dr. R. Bell; Sketch of the Coastal Topography of the North Side of Lake Superior, by Dr. A. C. Lawson.

with apparently the same correlative uplifts to the east and to the west, when on reaching the level of the 775–705 feet shore line in the basin of the Great Lakes there was another halt. This shore line is also recorded in the St. Lawrence Valley, though now shown at various altitudes and in various positions. The two higher strands north of Ontario and Erie Lakes then became slightly tilted towards the northeast.

3. Another downward movement of the central axis following, the formation of the "Iroquois beach" took place on the one hand, and corresponding shore lines at low levels in the St. Lawrence Valley on the other. The upper shore lines, both on the east and west of the central oscillating axis, would now slope towards it, though they have since returned nearly to a horizontal attitude.

4. Following was a period of moderate oscillations along the axis referred to, some downward and some upward, the forces producing them having apparently been largely spent, or having approached an equilibrium. These changes resulted in the breaking down of the strands along the margin of the oscillating zone on both sides, and in a considerable amount of denudation taking place. Lake Ontario was probably lower than at present, perhaps nearly or quite at sea level.

5. A slow series of reverse movements then set in which consisted mainly in a rise of the crystalline axis. This has continued to the present day with correlative subsidences in the areas formerly uplifted to the east and west. These changes are evidenced by the fact that the "Iroquois beach," which was, just previous to this period, in a horizontal attitude, is now tilted to the southwest, and similar movements, though in a reverse direction, have taken place in the St. Lawrence Valley, the raised shore lines there now sloping eastward longitudinally. What the amount of the uplift at the Thousand Islands has been since, it is difficult to say. Judging from the present levels of the "Iroquois beach" it would seem as if the rise must be fully 200 feet; but the hinge or axis of the movement may not have been at the eastern end of the existing beach.

The oscillatory movements of the barrier referred to would seem to have been limited and slow, nevertheless they affected, it appears, not only the granite axis, but a wide tract of country on either side, beyond which, as shown, complementary movements occurred. Even when the axis was at its lowest level, however, Lake Ontario must have been somewhat higher than the sea or gulf; for there is evidence of an eastward flow of the lake waters at this stage. Stratified beds of gravel and sand showing deposition in waters flowing in the direction indicated were found upon the granite axis at altitudes of 800

to 850 feet, or 300 to 400 feet higher than similar deposits on either side; and yellow sands and gravels containing concretions, common in the basins of Ontario and Erie lakes, were observed in the marine area to the east overlying the Saxicava sands and Leda clay, which must also have been carried down by an overflow of the lake waters.

The discussion of the causes of these oscillatory and complementary movements will have to be reserved for the present. It may be remarked, however, that it is only reasonable to assume that in the folding and compression of the rocks of the Northeast Appalachians along the border of the large Archean area to the north, there must necessarily have been transverse thrusts and uplifts along certain lines of weakness, though most of these have hitherto been supposed to antedate the post-Tertiary period. Three of these apparently crossed the St. Lawrence basin,—one at the Thousand Islands, a second along the line of igneous intrusions crossing the St. Lawrence Valley at Montreal, and a third at Quebec city.

The foregoing explanation of the phenomena is offered tentatively, though the writer has observed all the facts in the field and feels confident that it is to geomorphic changes we shall have to look for a solution of the problems presented in regard to the elevated strands and the origin of the basins of the Great Lakes themselves. The theory, it will be seen, includes only one downward movement with three or four pauses or temporary cessations of the stresses producing them, and one upward movement, still in progress, the latter proved to some extent by observations made by Professor G. K. Gilbert of the United States Geological Survey.* The geomorphism which has taken place outside of the St. Lawrence basin is not considered in this note; it is thought, nevertheless, that the changes there will all harmonize with those outlined in this paper. It seems to the writer that the theory is a more rational one, and more in accordance with observed geological phenomena, than that of glacial dams. The author is convinced that when the history of the great changes of level which have occurred in the region in question during the post-Tertiary period comes to be studied more in detail, geomorphology will be found to constitute an important factor, and along with denudation, enable us to explain the conformation of the surface features without resort to such adventitious and epigene agencies as are sometimes employed.

Ottawa, Canada, June 22d, 1904.

* Recent Earth Movements in the Great Lakes Region, Eighteenth Annual Report, U. S. Geological Survey, 1896–7, part ii, pp. 601–647.

ART. XXIII.—*The Material and Shape of the Rotating Cathode*; by H. E. MEDWAY.

[Contributions from the Kent Chemical Laboratory of Yale University—CXXX.]

IN a previous article from this laboratory* a method has been described for the rapid, electrolytic precipitation of metals upon a rotating platinum crucible made to serve as a cathode. In the present paper is given the record of experiments with other and cheaper metals, used in place of the more expensive platinum, as well as cathodes in the form of discs.

Experiments were made with a silver crucible of 50^{cm^3} capacity, carefully cleaned, dried at 100° C., weighed and adjusted to the rubber stopper which serves to hold the crucible and press against its inner wall two platinum strips which make the electrical connection.

Into the electrolytic cell was put an acidulated solution of copper sulphate, standardized by deposition of copper upon the rotating crucible of platinum.

Deposition upon Silver.

	Copper taken. grm.	Copper found. grm.	Error. grm.	Current. Amp.	N. D. 100.	Time. min.
(1)	0·1088	0·1086	−0·0002	2·	6·6	15
(2)	0·1088	0·1090	+0·0002	2·	6·6	15
(3)	0·1088	0·1084	−0·0004	1·5	5·	15
(4)	0·1088	0·1085	−0·0003	2·	6·6	15
(5)	0·1088	0·1080	−0·0008	2·	6·6	15
(6)	0·1041	0·1041	+0·0000	2·	6·6	15
(7)	0·1041	0·1046	+0·0005	2·	6·6	15
(8)	0·1041	0·1039	−0·0002	2·	6·6	15

The results of these experiments would seem to indicate that the use of a silver crucible leaves little to be desired so far as accuracy is concerned.

To remove the copper from the crucible, the deposit was rubbed off as much as possible and the rest dissolved in a strong boiling solution of hydrochloric acid, and this was accomplished with but trifling loss of silver, as is shown in the statement below:

	I.	II.
Weight of crucible before treatment	36·0089	36·0062
Weight of crucible after treatment	36·0062	36·0041
Loss of silver	0·0027	0·0021

* Gooch and Medway: This Journal, xv, 320, 1903.

Since the crucible should in any event be weighed before each determination, such small loss does not seriously affect the availability of the silver crucible as a substitute for platinum.

Similar experiments were made with a nickel crucible of 50^{cm^3} capacity, under a procedure exactly the same as that described, with the results as recorded.

Deposition upon Nickel.

	Copper taken. grm.	Copper found. grm.	Error. grm.	Current. Amp.	N. D. 100.	Time. Min.
(1)	0·1041	0·1028	−0·0013	1·5	5·	15
(2)	0·1041	0·1054	+0·0013	2·	6·6	12
(3)	0·1041	0·1036	−0·0005	2·	6·6	15

These results show that while nickel may be employed as a cathode, too much reliance must not be placed upon results obtained by its use when the greatest exactness is required. Care must also be taken in drying the crucible, since nickel is very easily oxidized with a consequent increase in weight. The deposit of copper was removed from the crucible with nitric acid, with considerable loss of nickel, as the following will show:

	I.	II.	III.
Weight of nickel crucible before treatment	17·6478	17·6161	17·6091
Weight of nickel crucible after treatment	17·6161	17·6091	17·5932
Loss of nickel	0·0317	0·0070	0·0059

So it appears that, while the silver crucible may with some economy and without sacrifice of accuracy be substituted for the platinum crucible used as a rotating cathode in the electrolytic determination of copper, the ease with which the crucible of nickel is attacked, both during the analytical process and in the subsequent removal of the deposit, is a bar to the use of that metal for the rotating cathode.

Shepherd* recommends the use of the ordinary disc anode of platinum as the rotating cathode, in place of the platinum crucible, while a stiff platinum wire, carried in semi-circular conformity to the edge of the disc cathode, serves as the anode.

According to my experience with this form and adjustment of apparatus, the deposits obtained are not so adherent as might be desired and tend to crumble away from the edge of the disc; and the same thing is true of discs of copper and silver. The probable reason for failure to obtain an adherent

* Jour. Phys. Chem., vii, 508, 1903.

deposit is that the edge of the disc, being nearer the anode, receives more current and larger deposit of copper than the central portions, with the consequence that the deposit upon the edge, built out and fragile, tends to break off under the rapid rotation of the disc. To remedy this defect, I have used for an anode a strip of platinum extending across the cell under and parallel to the rotating disc, so that the current may be equalized all over the disc. With the apparatus arranged in this manner, the following very good results were obtained in the precipitation of copper.

Deposition upon the Platinum Disc.

	Copper taken. grm.	Copper found. grm.	Error. grm.	Current. Amp.	N. D. 100.	Time. min.
(1)	0·0670	0·0672	+0·0002	2·	12	15
(2)	0·0670	0·0668	−0·0002	2·	12	15
(3)	0·0670	0·0666	−0·0004	2·	12	15
(4)	0·0670	0·0671	+0·0001	2·5	15	15
(5)	0·0670	0·0670	±0·0000	2·	12	15

The attempt to substitute aluminum for platinum, though the former metal has been recommended by Hough,* as material to receive the deposit, was not successful, owing probably to the film of aluminum oxide always present. Various measures were taken to remove this film—e. g., the aluminum was treated with hydrochloric acid and quickly transferred to the solution, a few drops of hydrofluoric acid added before the current was passed—but all to no avail, the copper falling off as fast as deposited.

From my experience, it seems that the disc is inferior to the crucible for use as a rotating cathode. Not only does the disc fail to hold the deposited copper as well as the crucible, but there are difficulties of manipulation which render the drying and weighing of the deposit upon the disc comparatively inexact.

* Jour. Am. Chem. Soc., xx, 302.

ART. XXIV.—*Structure of the Upper Cretaceous Turtles of New Jersey: Lytoloma;** by G. R. WIELAND. (With Plates V–VIII.)

IN 1865 Leidy described as *Chelone sopita* certain chelonian marginals from the Upper Cretaceous or Greensand of Tinton Falls, Monmouth county, and several others from Mullica Hill, Gloucester county, New Jersey. One of these specimens, including three left marginals and part of a fourth, was figured as the type.†

In 1870 Cope established his genus *Lytoloma*, at the same time making a not very clear reference of Leidy's *Chelone sopita* to both *Propleura* and *Lytoloma*.‡ The type species of the latter genus, *L. angusta*, as figured, is seen to consist of a single marginal and fragmentary lower jaw with a remarkably long symphysis. Bearing in mind, however, the closely associated manner in which the numerous forms from the New Jersey Greensand occur, there is at present no positive proof that this marginal and lower jaw belong to the same individual or even species, although both these possibilities are probable.

The close resemblance of the lower jaw of *Lytoloma* to that of *Chelone crassicostatum* (Owen, 1849)§ was noted by Cope. The latter type consists of a skull and lower jaw articulated in normal position, and is a rarely perfect specimen. It was more completely freed from its matrix,—a hard septarian nodule from the London Clay (Lower Eocene), and further illustrated and described, by Lydekker, in 1889, as *Lytoloma crassicostatum*.‖ Its generic relationship to *L. angusta* of the New Jersey Greensand, and to the lower jaw from the Landenien (inférieur) of Erquellinnes, Belgium, first described by Dollo as *Pachyrynchus*,¶ and later referred to Euclastes,** appears to be unquestioned.

* The first paper of this series, on *Adocus*, *Osteopygis*, and *Propleura*, was published in this Journal, Feb., 1904. The third paper will be on *Agomphus*.

† Cretaceous Reptiles of the United States, Smithsonian Contr. to Knowl., vol. xiv, 1865, pl. xix, fig. 5.

‡ Extinct Batrachia, Reptilia and Aves of North America, 1869, pp. 140, 145; and pl. xi, figs. 1–1b.

§ Fossil Reptilia of the London Clay, Part I. Chelonia, Paleontographical Society, p. 27, pl. xi.

‖ On a skull of the Chelonian genus *Lytoloma*. Proc. Zool. Soc., London, 1889, pls. vi, vii.

¶ Les Cheloniens, Landeniens (Eocène inférieur) de la Belgique, Bull. Musée Roy. d'Hist. Nat. de Belg., t. iv, No. 3, Juill, 1886.

** With reference to the priority and synonymy of the species here discussed, it is necessary to note that the skull *Euclastes platyops* Cope was first mentioned in 1867; hence *Euclastes* antedates *Lytoloma* two years. Moreover, according to Dollo (Sur le Genre *Euclastes*, Ann. Soc. Geol. du Nord., t. xv, p. 114, Mars, 1888) *Euclastes* includes *Chelone* Owen, 1841; *Lytoloma* Cope, 1871; *Glossochelys* Seeley, 1871; *Puppigerus* Cope, 1871; *Pachyrynchus* Dollo, 1886; *Erquellinesia* Dollo, 1887. But later Boulenger and Lydekker (Geol. Mag., Dec. 3, vol. iv, p. 270, 1887), pointed out that *Euclastes* is preoccupied; thus the later name *Lytoloma* becomes valid.

It is thus seen that the cranial characters of *Lytoloma angusta* Cope are inferentially known and point conclusively to a position in the Cheloninæ, although as yet no adequate description of a Lytoloman carapace from the Greensand of New Jersey has been given. It is therefore of distinct interest to find that the Yale specimen No. 625 proves to be a fairly complete carapace, with marginals so distinctly like those of *L. angusta* as to indicate their specific identity. Moreover, the rather close relationship to *Propleura*, and the various primitive characters present, add to our knowledge of the early marine forms, and bring us a step nearer to the actual lines of descent of existing marine turtles from littoral forms. While not known to have survived beyond the Eocene, the Lytolomas show by their structure that they were not more than generically removed from the existing genus *Chelone*. Before passing on to the description of the carapace, however, it will, because of the extended synonymy just reviewed, the considerable number of years since the collection of the materials from New Jersey, and the fragmentary condition of many of the specimens, be necessary to note briefly the evidence as to accompanying cranial characters.

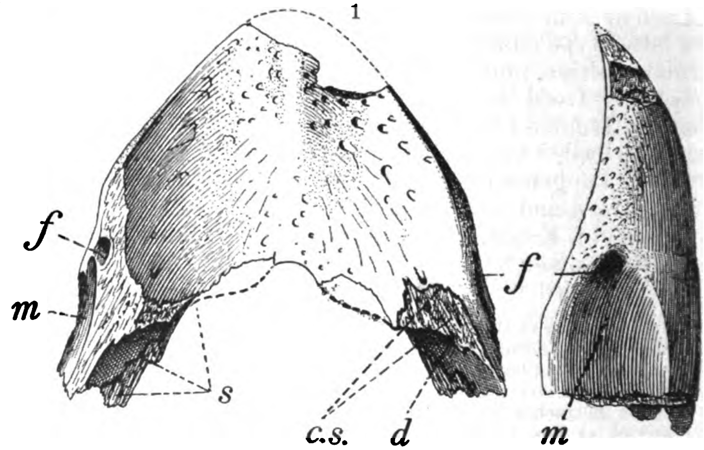


FIGURE 1.—*Lytoloma angusta* Cope. Superior and lateral view of Dentalium. ×⅘. (Y. S. 913, from Upper Cretaceous Greensand of Hornerstown, New Jersey. *c. s.*, coronoid suture and sutural surface; *s*, splenial suture and sutural surface; *d*, dental foramen (orifice slightly arched over); *f*, nutrition foramen (for mandibular branch of jugular vein—Bojanus); *m*, masseteric fossa (insertion of masseter muscle).

The Lower Jaw.

Evidence of the specific association of lower jaws and marginals of the *Lytoloma angusta* form is not abundant in the Yale collections, though fairly conclusive. A dentalium which is accompanied by a fragmentary but characteristic marginal is

shown in figure 1. Several more or less isolated jaws of the same form attain about double the size of that illustrated.

The relative width of the lower jaw of *Lytoloma* is much greater than in the living Chelonians. Its further peculiarities are mainly to be observed in the dentalium, notable for its remarkably long symphysis and very large pits for the insertion of powerful masseter muscles. These specialized features primarily suggest a *conchifragous habit.** The massive imperforate palatal surface described below also strongly supports the view that these Lytolomas had become littoral conch-eaters, finding their home and an abundant supply of mussels and other "shell fish" on the New Jersey Cretaceous shore lines.

The Cranium.

With the exception of *L.* (Euclastes) *platyops* Cope no further *Lytoloma* crania from the Upper Cretaceous of New Jersey have been figured. The only specimen in the Yale collection referable to the genus is an isolated anterior portion of a skull, which is, however, in a wonderful state of preservation, as shown in the accompanying text—figure 2 (A, B, and C). There is no means of now determining with certainty whether or not this specimen is a *Lytoloma angusta.* It is quite possible that the lower jaw pertaining to it had a somewhat differently shaped coronoid region than that of *L. angusta.* Rather than erect a new species on such slender evidence, it may suffice to refer to this rare and interesting specimen by number when comparing its characters with those of other forms. With *L. platyops* Cope† this comparison is as follows:—

Lytoloma (Euclastes) *platyops* Cope.	*Lytoloma*, Yale specimen No. 913a.
1. "Maxillaries and palatines separated throughout by the prolonged vomer."	1. Maxillaries and palatines *probably* separated throughout by elongate vomer.
2. "Posterior nares opposite palatal front margin of orbits" (? ?).	2. Internal narial opening well back from both the lower (palatal) and the upper (orbital) anterior border of the palatines.
3. "Premaxillary margin projecting beak-like;" alveolar face little concave.	3. As in *L. platyops;* that is, premaxillaries projecting more than in the Chelonidæ, but not forming a projecting and decurved beak as in either *Chelydra* or *Archelon*.
4. "Vomer forming a central ridge."	4. Outer (or palatal) surface of vomer flat anteriorly but raised between the palatines.
5. Floor of nasal meatus perforate for hook of mandible.	5. *Floor of nasal meatus imperforate and very thick.*
6. "Nostrils superior behind the short projecting beak (not borne on a projecting muzzle)."	6. As in *L. Platyops* (not *Bothremys*).

* Dollo, Première Note sur les Cheloniens landeniens (éocène inférieur) de la Belgique, Bull. Musée Roy. d'Hist. Nat. de Belg., t. iv, No. 3, p. 138, 1886.

† Loc. cit., p. 148.

In both the above skulls (borrowing further from the description of *L. platyops*, as given by Cope), the descending portion of the prefrontal is very wide, and equal to the width of the maxillary outside the small lachrymal foramen. Inter-

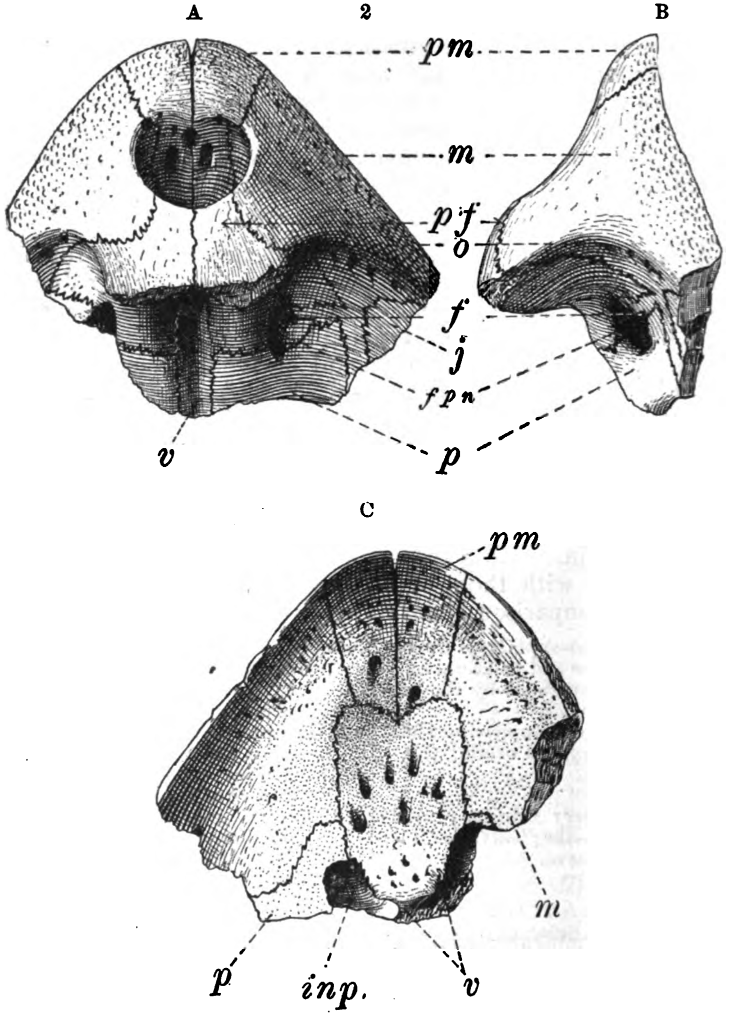


FIGURE 2.—*Lytoloma angusta* ? Anterior portion of cranium. × ½. Yale specimen 913a. From the Upper Cretaceous of Hornerstown, New Jersey.
A, superior,—B, right lateral,—C, palatal view.—*pm*, premaxillary; *m*, maxillary; *pf*, prefrontal; *o*, anterior border of orbit; *f*, foramen (*alveolare superius* ? ?); *fpn*, *foramen palatino nasal;* *j*, jugal; *p*, palatine; *v*, vomer; *inp*, internal narial passage (the vomero-palatine wall being partly broken away).

nally the columns of the prefrontals converge below nearly to an acute angle and are directed forward, also much backward in *Lytoloma* (Yale specimen No. 913a), thus forming a strong internal base on the vomer. They restrict the nasal meatus, leaving its diameter less than that of the columns.

The internal nares in the present specimen open far back; but the long, broad, and massive vomer is fairly complete, and it is not likely that the palatines closed in behind it to further roof the narial passage. If so, herein may lie a marked difference from the still more specialized Eocene Lytolomas from the London Clay and the Landenien inférieur of Belgium. In describing the skull of *Lytoloma crassicostatum* Owen, Lydekker says: "one of the first points which strikes the observer [on comparison with *Thalassochelys*] is its extreme shortness, the width at the widest part of the temporal arch being exactly equal to the length from the occipital condyle to the muzzle; whereas in the Loggerhead the former diameter is considerably less than the latter, whilst in *Chelone* the difference between the two diameters is still greater. Still more noticeable is the backward position of the posterior nares, which are situated at a point one third the distance from the condyle to the muzzle, as indeed is mentioned in M. Dollo's description of the Belgian specimens. In that description it is, however, stated that the boundary of the posterior nares is formed by the development of the palatal plates from the pterygoids. So far, however, as can be seen from the present specimen, it would appear that this border is really constituted by the palatines, since on either side there seems to be a distinct suture separating the bones forming the border of the posterior nares from the undoubted pterygoids. Looking at the arrangement of the palatines in the Loggerhead, it would seem much more natural that these should be prolonged backwards, rather than that the pterygoids should assume the condition assigned to them by M. Dollo. In either case the vomer is excluded from the posterior nares, but its position anteriorly is not shown in this specimen." (It is obscured by the lower jaw which is in place.)*

The Carapace and Plastron.

The specimen (Yale Catalogue, No. 625) on which the following description is mainly based was received from the West Jersey Marl Company, May 1, 1869. It is from the old, long unworked marl pit, one and one-half miles east of the village of Barnsboro, Gloucester county, New Jersey. Willows, holly, pine, etc., now grow scatteringly over this area of former excavation some thirty acres in extent, which has yielded so many other interesting fossils, among them the remarkably fine carapace and plastron *Osteopygis Gibbi*.

* Lydekker, loc. cit.

The recovered portions of the present specimen, shown in detail by the stippled areas in Plate VIII, consist of (*a*) the third, fifth and sixth neurals; (*b*) the antero- and postero-pygal; (*c*) the pleuralia of the right side less the free-rib tips, but with the inner or neural borders of all but the second distinct; (*d*) the first to the fifth pleurals inclusive of the left side, the free-rib tips of the second and fifth being present, also a fragment of the seventh pleural, as indicated by its form and the postero-lateral furrow of the fourth vertebral horn-shield which crosses it; (*e*) the fourth to the seventh inclusive, and the ninth marginals of the right side, and the fourth to the eleventh marginals inclusive of the left side, with the anterior half of the pygal marginal. There are also some fragments of the accompanying plastron, which, although too incomplete to permit the exact restoration of any of the plastral elements, indicate a plastral form even more reduced than, but otherwise much like that seen in *Osteopygis* and *Propleura.*

With the exceptions mentioned, all parts of the carapace, as far as recovered, are uncrushed and but little broken. As sent to the museum, they were dissociated, but the sutures are well preserved and almost without exception interlock in their normal position, so that it is possible to determine these elements, as well as the general form of the carapace. The fortunate presence of the third neural, with both the adjoining third pleurals as well as two rib tips of the left side, leaves no doubt as to the width of the carapace. Moreover, the borders of the missing second, fourth, seventh, eighth, and ninth neurals are indicated exactly, and those of the first neural approximately. The anterior sutural border of the first left pleural being complete, there can be little doubt but that the nuchal had approximately the outline indicated in Plates VI–VIII. The length of the missing three anterior marginals can only be inferred, but must be nearly that shown in outline.

With regard to the general form of the marginals and of the posterior neurals in the present genus, and in *Osteopygis* and *Propleura*, figures 3–6 in the text afford data for exact comparison. Taken in conjunction with the facts already given, they require little further description. It may only be noted that the specimen represented in figure 5 shows a diminution of the posterior neurals more marked than that in *Osteopygis Gibbi*, while the condition in *Propleura*, figure 6, is more like that of the present form.

As indicated in Plates VI and VII, the horn-shield furrows are all distinct and rather broad. The carapace is of sub-orbicular outline, being broadest across the posterior end of the fifth neural. In this respect it is somewhat intermediate between cordate forms like those of the existing Cheloninæ

and the Osteopyges, which are broadest across the anterior end of the sixth neural. In the present more primitive turtle the cordate form of the Chelonine carapace is beginning to appear, the swinging back of the eighth rib into a pit of the eleventh marginal, and the consequent leaving of the tenth

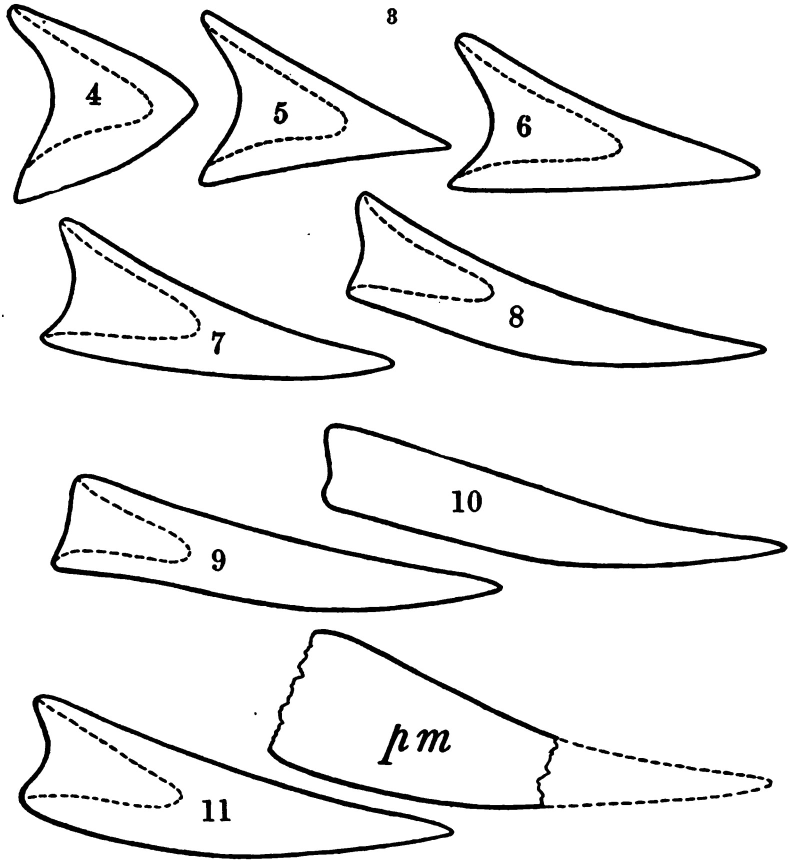


FIGURE 8.—*Lytoloma angusta* Cope (Yale specimen 625). Natural size. Vertical middle transverse section through the 4–11, and pygal (*p m*) marginals. Respective rib pits in dotted outline.

marginal without a supporting rib, as in *Chelone*, having already occurred. Compare plates V and VI. In *Osteopygis Gibbi* the femur is longer than the humerus, and from general comparison it may be argued that in the present species of *Lytoloma* the femur is relatively shorter than in *Osteopygis*, but not so shortened as in the existing marine turtles. This intermediate development is an important point.

In addition to the fragmentary portions present, the general form of the *plastron* is in part indicated by the marginals. The digitations of the antero-external limb of the hyoplastron projected into several small shallow pits in the lower border of the posterior half of the fourth and the anterior half to three-fourths of the fifth marginals, thus forming a dactylate junction

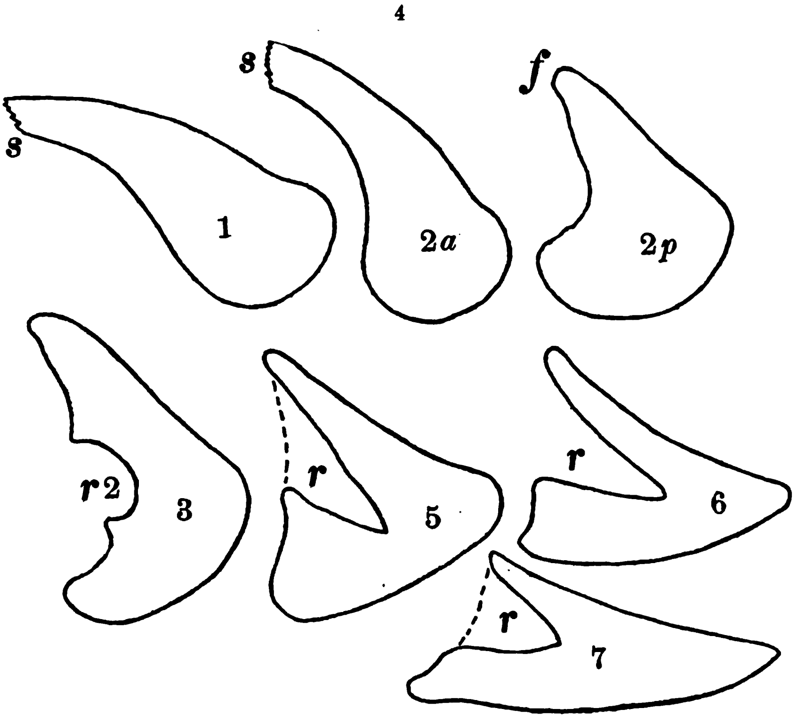


FIGURE 4.—*Propleura borealis* Wieland (type). × ⅘. Vertical, middle, or end transverse sections of marginals for comparison with the marginals of *Lytoloma* shown in figure 3.

1, 3, 5, 6, 7, middle sections numbered respectively; *2a*, *2p*, anterior and posterior end outline (or section) of second marginal; *s*, *s*, inner border of first and second marginal (uniting by suture to first pleural and not free as in *Lytoloma*); *f*, free border; *r2*, claw-shaped furrow in third marginal for reception of second rib; *r*, *r*, *r*, rib pits in 5–7 marginals for reception of respective, *i. e.* 3–5 ribs.

6·5 to 8^{cm} in length. This is a distinctly shorter junction than in *Osteopygis*, in which the outer hyoplastral limb extends forward to the second marginal, and is about equal in extent to that seen in *Eretmochelys*. No distinct pits for the reception of the outer digitations of the hypoplastron exist in the fossil at hand. In the Osteopyges, these are present for both limbs of

the plastron, marginals 2 and 8 being deeply pitted for the extreme ends of the hyo- and hypoplastron, respectively, as explained in the description of *O. Gibbi* and *Propleura.* In

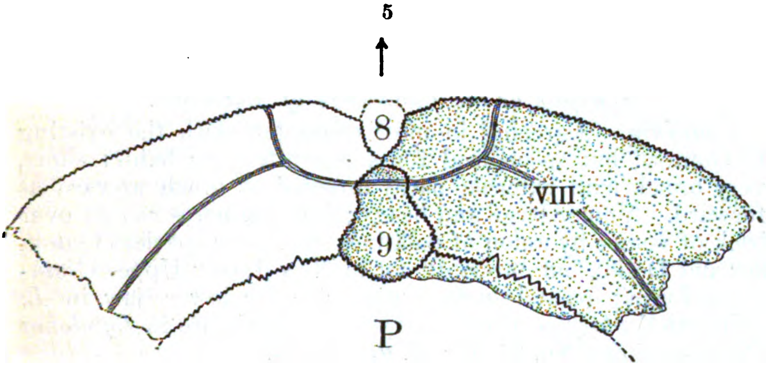


FIGURE 5.—*Osteopygis* sp. (Yale specimen 908). $\times \frac{1}{3}$. Right eighth pleural with the ninth neural and a portion of the antero-pygal (P) attached. Horn-shield borders of fourth and fifth vertebralia and fourth costal horn-shields distinct and shown in triple line. (Thickness of neural is ·7 cm.)

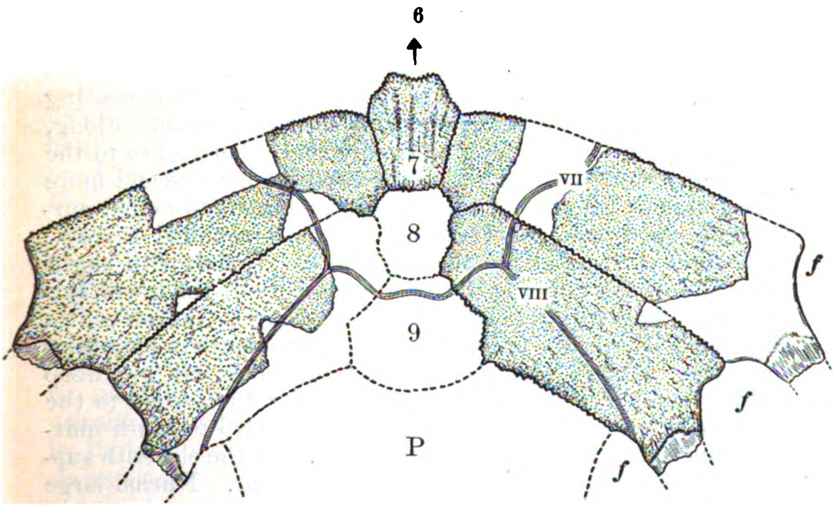


FIGURE 6.—*Propleura* sp. (Yale specimen 559). $\times \frac{1}{8}$. Right and left seventh and eighth pleuralia and seventh neural with borders of the fourth and fifth vertebral and the fourth costal horn-shields distinct and shown in triple line. Stippled portions only preserved. 7–9, neuralia; VII, VIII, pleuralia; P, antero-pygal; *f, f, f,* the three posterior pleuro-marginal fontanelles. (Thickness of pleuralia at sutural edge ·3–·5 cm.) Barnsboro, New Jersey.

the living Cheloninæ, the marginal pits for the plastral digitations are indistinct. Hence, *Lytoloma* is also intermediate in this respect.

Adocus, *Osteopygis*, *Lytoloma*, and *Chelone* thus *virtually* form a series passing from a strong cleido- to a weak dactylosternal plastral junction. The large anterior and posterior plastral foramina and the elongated entoplastron, however, are distinct departures from such a plastron as that of *Adocus*, leading to the plastral form seen in living sea turtles.

Synopsis of the Characters of Lytoloma.

Cranium.—Agreeing in most characters with the existing Cheloninæ, but specialized for a conchifragous habit; short, very broad, with external nares directed as much upward as forward. Vomer large and heavy; internal nares roofed over back of vomer by union of palatines in Eocene species (Lydekker and Dollo), but probably not in New Jersey Upper Cretaceous forms; palatal surface perforate for lower jaw in *L.* (*Euclastes*) *platyops* Cope, heavy and imperforate in *Lytoloma* (Yale specimen No. 913a = *L. angusta?*).

Lower Jaw.—Short and broad, with a very long symphysis, and wide and deep lateral pits for the attachment of heavy masseters.

Carapace.—Suborbicular in outline, with wide and persistent pleuro-marginal fontanelles; composed of 51 bony plates with the boundaries of the (38) horn-shields distinct, the numerical agreement thus being complete in *Osteopygis*, *Propleura*, and *Chelone*. Marginals 11 pairs, narrow anteriorly, but increasing in breadth to the eleventh, which is nearly as broad as long, with outer borders forming an evenly continuous curve to the eighth marginal, beyond which the carapace is more and more emarginate at the ends of the marginals, upper and nether surfaces of equal area, inner surface a shallow rounded furrow; both outer surfaces of fourth marginal nearly flat, with slight concavity of the upper surface and convexity of the lower surface beginning with the fifth and increasing to the eleventh, supported by rib tips only, and upper inner borders bounding the series of large pleuro-marginal fontanelles; rib pits deep and of round to elliptical section, those for the second to the eighth ribs being borne posteriorly on the third to ninth marginals inclusive, the tenth marginal ribless and the eleventh supporting the ninth rib anteriorly, as in *Chelone*. Nuchal large and broad. Neuralia (9) without marked tendency to the suppression of any of the final members of the series, as in *Adocus* and *Osteopygis*. Antero- and postero-pygal as in *Chelone;* surface of the plates smooth, not pitted, and as in the living Chelonians.

Horn-shields.—(38 in number) agreeing numerically with those of *Chelone*. Vertebralia broader than long.

Plastron.—Much as in *Osteopygis*, but with a narrower

bridge (as indicated by fragmentary portions accompanying Yale specimen No. 625, and by marginals 4 and 5).

Limbs.—Little known; humerus and femur thalassoid, and of nearly equal development.

Habitat.—Infralittoral. *Habit.*—Conchifragous.

Range.—Upper Cretaceous and Lower Eocene of Europe and America.

*Systematic Position of Lytoloma and of Osteopygis.**

Where shall we place *Lytoloma*, which in common with *Osteopygis* and *Propleura* has a reduced and somewhat *Chelydra*- or *Staurotypus*-like plastron, and a distinctly *Chelone*-like carapace? It is my belief, based on certain somewhat fragmentary fossils which it is proposed to illustrate later, that in the New Jersey Upper Cretaceous there were already present forms more nearly related to *Chelone* than is *Lytoloma*, although as Dollo well suggests such are far rarer than has been assumed. Second, the free tenth marginal of *Lytoloma* indicates that the swinging back of the ninth rib (or eighth and ninth ribs), thus leaving the ninth or tenth marginal, as the case may be, without rib-support, took place early, and was correlated with the shortening of the femur and the development of heavy front flippers. Third, it appears that *Osteopygis* and *Propleura* belong to a side line, with long and still chelic femora, which never accomplished the rib change just mentioned and did not survive; and fourth, *Lytoloma* originally sprung from this side line. If so, the latter genus developed by parallelism a carapace which, with the skull (that of *Osteopygis* being yet unknown) and the thalassoid humerus, brings it so near to *Chelone* as to make necessary the inclusion of both these genera in the same subfamily.

Having settled this point, the question remains as to whether the two genetic groups containing *Osteopygis*, *Propleura*, and *Lytoloma* on the one hand, and the living members of the Cheloninæ and their more direct ancestors in the other, shall be included in the same subfamily. *Osteopygis*, the most primitive of all the forms in question, is removed from *Chelone* by its less modified limb structure, with all or nearly all the claws present; by its less reduced marginals, consecutively rib-

* In my first paper on the Upper Cretaceous Turtles of New Jersey (this Journal, vol. xvii, Feb., 1904), the opinion was tentatively expressed that *Osteopygis* and *Propleura* might best be separated in a distinct family, namely Cope's Propleuridæ, but the utmost degree of separation any one might suggest, now that *Lytoloma* has been more closely considered, would be as a subfamily,—the Propleurinæ. The position now assigned to these forms is virtually that given them in a provisional classification of marine turtles, proposed earlier (this Journal, vol. xiv, p. 108, 1902), and to which I shall as yet adhere, although recognizing with Dollo the great difficulty, if not impracticability, of satisfactorily dividing the Cheloniidæ into subfamilies in the present imperfect state of our knowledge of the group.

supported; by the absence of pleuro-marginal fontanelles and the nether articular process of the nuchal, and finally by its mere *Chelydra*-like pelvis and earlier type of plastron. Doubtless there are also cranial differences. There is, therefore, between *Osteopygis* and *Chelone*, when considered alone, a very distinct structural interim such as might well characterize two subfamilies. *Lytoloma*, however, is so exactly intermediate that taken with other forms, existing and extinct, there exists a nearly continuous morphological series, passing by simple generic or even lesser stages from the most specialized existing Cheloninæ back to *Osteopygis*. In fact the greatest hiatus remaining unbridged appears to be the ribless ninth or tenth marginal, as seen in *Lytoloma* and existing forms. I am at a loss to surmise if this condition was due to a slowly effected change, or was suddenly developed after the appearance of pleuro-marginal fontanelles in the early line, giving rise to the two genetic groups mentioned. In either case it must have been, as already hinted, correlated with femoral shortening and the development of strong front flippers, and is scarcely to be considered as of more than generic value. If a separation into two subfamilies were made, it would have to be based mainly on this feature, as furnishing the only sharp distinction.

The final conclusion must be that *Osteopygis* and *Propleura* can be placed in a separate subfamily, the Propleurinæ, on genetic grounds, but that further discovery may bring them very near if not into the Cheloninæ. Moreover, as has been seen, these forms, though not apparently forming a closed series, permit the statement that *Osteopygis* was no more than generically separated from some strongly web-footed littoral turtle, which was the true ancestor of the existing Cheloninæ.

The facts given in the present and preceding papers on the Upper Cretaceous turtles of New Jersey, as well as in my paper on *Toxochelys*, indicate the manner in which the marine turtles have been derived from generalized land forms, together with their line of descent. Aside from the carpal and tarsal changes involved and as yet but meagerly illustrated by fossil forms, the most interesting future discoveries will be the ancestral, littoral, and fluviatile Osteopygoid tortoises.

Measurements of Lytoloma.

(A) The dentalium of *Lytoloma angusta* (Yale specimen No. 913.) Uncrushed.

Width (measured from outer extremities of the coronoids)	7·5 cm
Distance (on median line) of hook from anterior ends of the coronoids	4·7
Length of median symphysis	4·2
Greatest vertical depth of median symphysis	1·1

(B) Anterior portion of the skull of *Lytoloma* sp. (Yale specimen No. 913 a = *L. angusta* ?.) Uncrushed.

Length of palatal surface of vomer	3·3
Width " " "	2·0
Length of palatal surface of premaxillary..........	2·7
Greatest width of palatal surface of premaxillary..	1·0
Greatest thickness of vomeral partition between the nares	1·1

(C) The carapace of *Lytoloma angusta*. (Elements uncrushed and disarticulated. Yale specimen No. 625.)

Length (estimated to within one or two centimeters)	58·
Breadth (greatest, as measured across anterior end of fifth neural).	53·

(1) *Bony Plates.*

	(a) Exact length on outer edge of carapace.	(b) Width along groove of horn-shields.	(c) Greatest thickness.
Nuchal	--	--	--
1st marginal....	--	--	--
2d "	--	--	--
3d "	--	--	--
4th "	5·5	2·5	·2·4
5th "	7·2	3 6	2·3
6th "	7·2	4·3	2·2
7th "	8·	4·8	1·8
8th "	8·	5·6	1·5
9th "	8·2	6·	1·3
10th "	7·5	6·	1·3
11th "	7·8	5·5	1·5
Pygal "	4·7	(5·5)	1·8

	Length on median line.	Greatest width.	Thickness.
Nuchal	----	----	--
1st neural	(5·0)	(4·0)	--
2d "	(5·0)	(5·0)	--
3d "	4·4	4·4	·6
4th "	(5·5)	(4·2)	--
5th "	4·1	4·1	·7
6th "	4·1	3·4	·7
7th "	(3·1)	(3·3)	--
8th "	(3·0)	(2·7)	--
9th "	(3·5)	(3·0)	--
Antero-pygal	3·7	8·0	1·1
Postero-pygal.....	6·0	(8·0)	--
Marginalo- "	6·0	4·7	1·8

	Length over curvature.	Median width.
1st pleural	20·	5·
2d "	24·	6·
3d "	25·	5·5
4th "	25·5	5·3
5th "	24·5	5·
6th "	22·	5·
7th "	19·	5·5
8th "	15·	5·

(The large pleuro-marginal fontanelles are approximately one-third the length of the pleurals which respectively bound them.)

(2) *Horn-shields.*

	Length on median line of carapace.	Greatest breadth.
Nuchal	----	----
1st vertebral	----	11·
2d "	10·	14·5
3d "	11·	13·5
4th "	11·4	15·
5th "	----	----

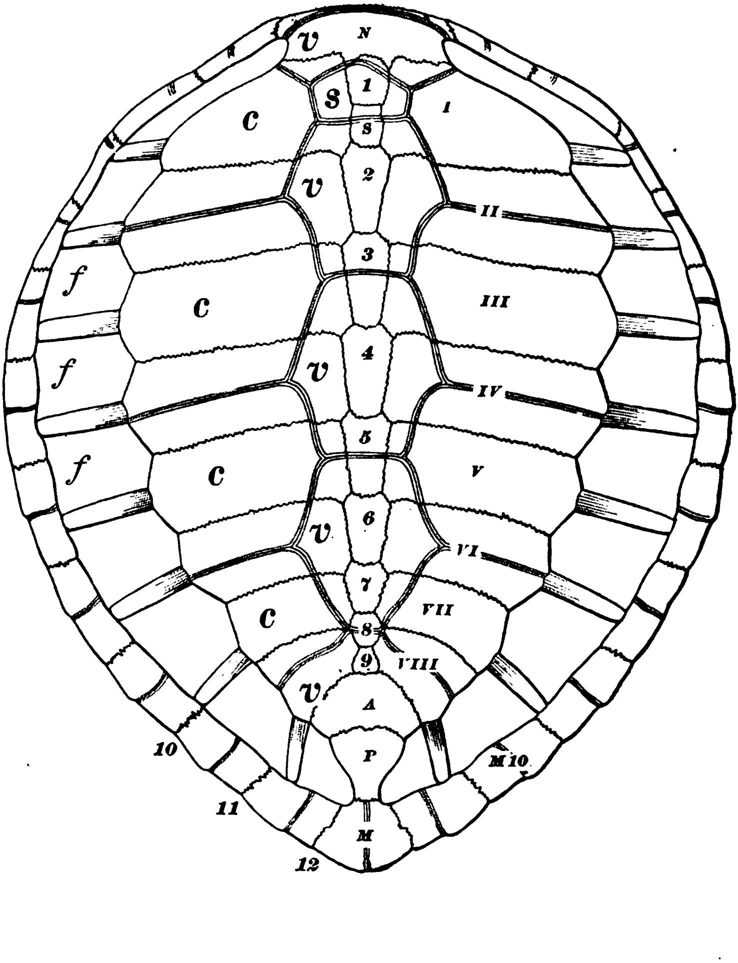
Length of fifth–eleventh marginal horn-shields, respectively, measured along outer border of carapace :—6·5, 7·5, 8·0, 8·5, 8·0, 8·0, 7·5.

LETTERING OF PLATES V–VIII.

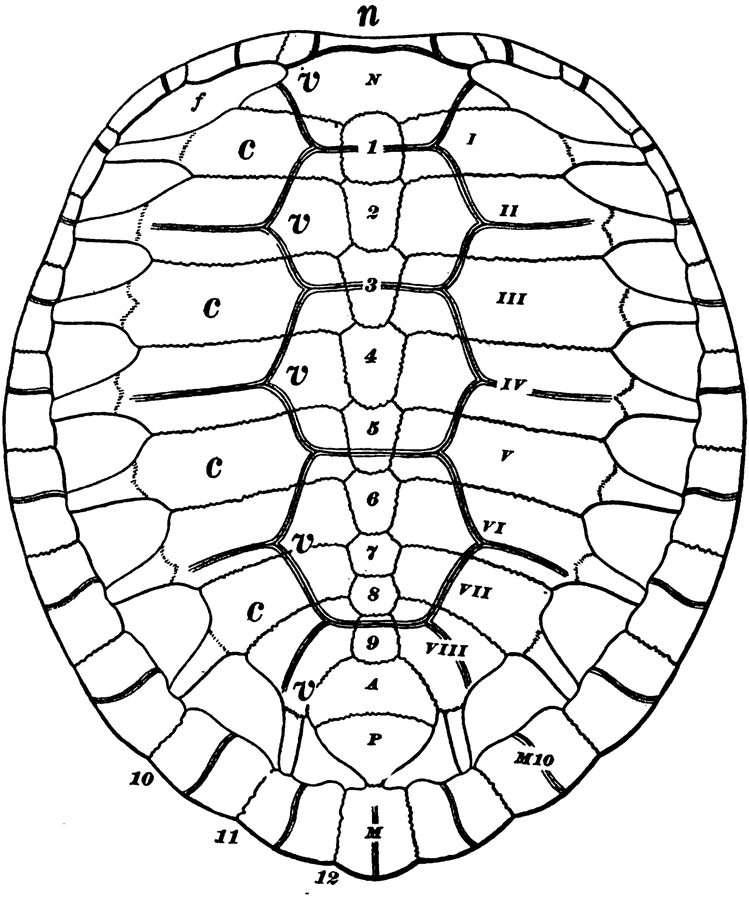
(a) Bone Plates :—*N*, Nuchal ; *1–9*, Neuralia ; *A*, Antero-, *P*, Postero-, *M*, Marginal-Pygal ; *I–VIII*, Pleuralia ; *M9–M11*, 9th–11th Marginals ; *s* (in Plate V), Supernumerary neural.

(b) Horn Shields :—*n*, Nuchal ; *v*, *v*, *v*, *v*, *v*, 1st–5th Vertebralia ; *c*, *c*, *c*, *c*, 1st–4th Costalia ; *S* (in Plate V), Supernumerary vertebral ; 10–12, Marginalia ; *f*, *f*, *f*, Pleuro-marginal fontanelles.

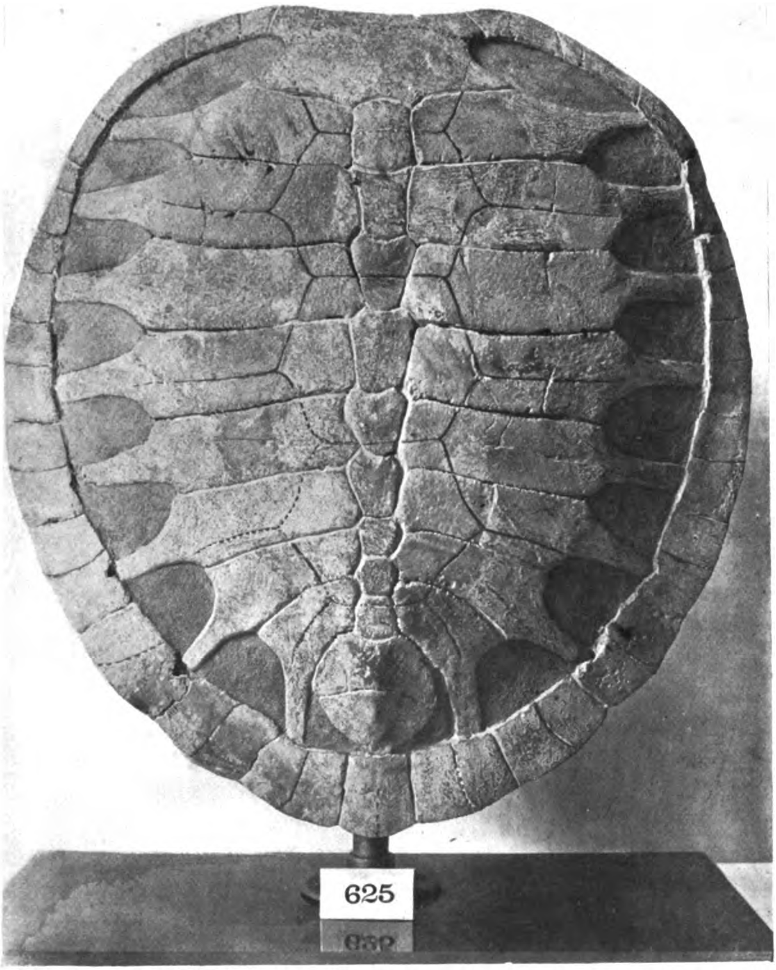
Yale University Museum,
New Haven, Conn.



Carapace of *Chelone mydas* L. (var. or sp. nov.) Southern Atlantic coast of the United States. A young specimen × ½. Free borders in smooth, sutures in zigzag, and boundaries of the horn-shields in triple line.

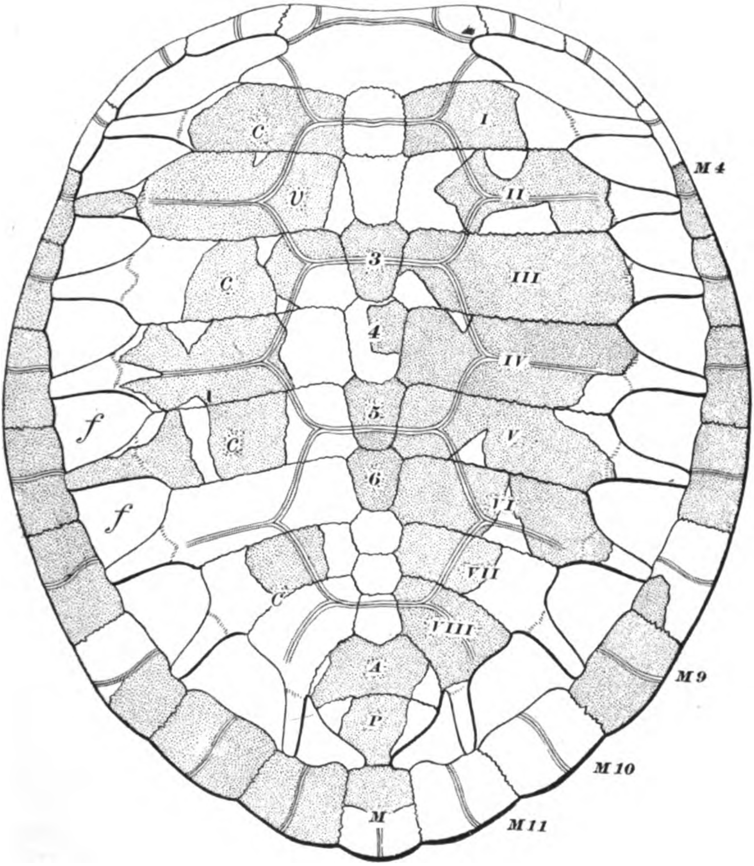


Carapace of *Lytoloma angusta*. × about ⅙. Drawn from the specimen shown in the following Plate, VII.



Carapace of *Lytoloma angusta* from the Upper Cretaceous Greensand of Barnsboro, Gloucester Co., New Jersey, as partly restored and mounted in the Yale Museum.—See Plate VIII.

Actual length of Carapace about 58 cm.



Carapace of *Lytoloma angusta.* × about ⅛. Diagrammatic figure. The stippled surfaces show the parts of the original specimen as recovered in a disarticulated and more or less broken condition. See Plates VI and VII.

ART. XXV.—*The root-structure of North American terrestrial Orchideæ;* by THEO. HOLM. (With figures in the text.)

FEW orders have offered a larger number of interesting data in the various phases of the life-history of plants than the *Orchideæ*. By their manifold structures, readily perceivable among their various biological types, they have for years attracted considerable attention and furnished ample material to writers on morphological and anatomical botany. It is quite natural that the epiphytic species have received a more general treatment than the terrestrial, on account of their unquestionable prominence in floral and vegetative characters, besides that their cultivation being less difficult has made them more accessible to study than the others. Among the terrestrial species very few have been studied from a general point of view except old-world species, but several of these have, nevertheless, served as the very basis of such magnificent contributions to science as those of Irmisch. While, thus, our native, terrestrial *Orchideæ* are very little known from a morphological and anatomical point of view, the following notes on their root-structure are offered as a small contribution to the knowledge of these interesting plants, with the intention to add some further observations in a subsequent paper, which we have made upon the other organs.

As a general result of these observations we might state here, that it seems to be a rule that a tuberous rhizome is only provided with slender roots as is the case with *Arethusa*, *Calypso*, *Bletia*, *Tipularia*, *Aplectrum*, etc., while species with slender rhizome may possess tuberous roots, as for instance: *Orchis spectabilis*, *Platanthera*, *Spiranthes*, etc., or the roots may be equally slender, as in *Cypripedium*, *Goodyera* and certain species of *Pogonia: verticillata*, *ophioglossoides* and *divaricata*.—We might, also, call attention to the fact, that the development of such varied structures of roots and rhizomes does not seem to be dependent upon any special nature of environment; on the contrary, species with tuberous rhizomes may occur in open bogs as well as in deep, shaded woods; and species with tuberous or slender roots may be found in bogs, ravines, in dry fields or in clearings in thickets. In this particular respect the plants themselves seem to possess a very pronounced individuality, and are difficult to classify as meso-, hydro- or xero-phytes. It appears even to be rather uncertain whether some of these species are to be considered as auto-phytes or hemisapro-phytes.—And when we consider the general structure of the roots alone, it seems quite

impossible to offer any satisfactory explanation as to certain facts, for instance, the presence of a velamen in *Tipularia discolor*, and its absence in *Aplectrum*, although the nature of the surroundings, the substrate even, is the same in both, and they both are terrestrial. In *Bletia verecunda*, on the other hand, the development of a similar velamen may be explained as an inherited character, since other species of the genus are epiphytic. A similar approach to the epiphytic root-type as demonstrated by certain species of *Spiranthes* is, also, very puzzling, inasmuch as this genus does not, otherwise, exhibit any analogies in common with epiphytes.

From these data, it may be readily appreciated that the *Orchideæ* are not to be classified in anything like natural sequence based upon root-structure alone, and we have thought, therefore, that it would be the most convenient to treat the different types of roots by themselves, and regardless of the natural affinities of the genera or species in question. In this way a general idea of the root-structure may be obtained with less difficulty.

The following types may be distinguished as characteristic of the terrestrial species:

A. Roots slender with the leptome and hadrome located in one central-cylinder.

B. Roots tuberous with the leptome and hadrome located in one central-cylinder.

C. Roots tuberous with several cylinders of leptome and hadrome.

Of these types the first, A, represents several cases of deviation from the ordinary root-structure by the presence of a velamen for instance (*Tipularia*, *Bletia*), by a peculiar striate thickening of cortex (*Liparis*), and by the development of a true pith (*Calypso*, *Goodyera*, *Habenaria*, etc.). The second type, B, is especially characteristic by reason of its large dimensions, due to numerous layers of cells in cortex and pith, while the third, C, as already indicated, possesses several mestome-cylinders.

Type A.

Cypripedium acaule Ait., *C. pubescens* Willd., *C. guttatum* Swtz., *C. montanum* Dougl., *C. fasciculatum* Kellogg, *C. Californicum* Gray and *C. arietinum* R. Br.

In the genus *Cypripedium* the root-structure comes nearest that of a normal root and may be described as follows: The epidermis is thin-walled in all the species enumerated above, with the exception of *C. guttatum*, in which the outer cell-wall is slightly thickened; root-hairs are usually abundant. A thin-walled hypoderm of one layer is, also, noticeable, but is

moderately thickened in *C. guttatum.* The cortical parenchyma consists of from 6 to 8 strata with large deposits of starch; it is quite compact, but thin-walled, except in *C. pubescens*, where the cell-walls are thickened and porose. Endodermis is mostly thickened as an U-endodermis outside the leptome, but it is otherwise thin-walled, and the following deviations may be mentioned. In *C. acaule, guttatum* and *arietinum* 3 to 4 thick-walled cells were observed outside the leptome, while 6 in *C. Californicum;* in *C. pubescens* and *C. montanum* 2 to 4 cells were thickened like an O-endodermis outside the leptome, while in *C. fasciculatum* the entire endodermis was found to be thin-walled throughout. The pericambium is only represented by a single continuous layer in all the species; it is thin-walled except in *C. arietinum.* The rays of the hadrome are very broad and meet in the center; they average from 5 to 10, 8 to 10 being the characteristic of *C. montanum;* a thick-walled pith forms a small central group in *C. Californicum*, but not in the others. The leptome is well developed in large groups alternating with the rays of the hadrome.

None of the roots were found to be contractile, and hyphæ were noticed in: *C. pubescens* (epidermis, hypoderm and cortex), *C. fasciculatum* (cortex) and *C. guttatum* (endodermis and pericambium).

Epipactis gigantea Dougl.

Epidermis, hypoderm and cortex are all thin-walled, and much starch is deposited in the cortical parenchyma. The endodermis is thin-walled throughout with the Casparyan spots plainly visible and with contents of starch; the pericambium forms a closed ring around the leptome and hadrome; it consists of only one layer, the cells of which are prominently thickened outside the leptome, but otherwise thin-walled. Five broad rays of hadrome extend to the center of the cylinder and alternate with large, roundish groups of leptome. No hyphæ were observed.

Listera cordata R. Br. and *L. australis* Lindl.

The structure of the roots of these two species is almost identical, and the difference depends merely upon the relative development of hairs, which are very numerous and long in the former species, but quite scarce in the latter; moreover, the leptome constitutes groups of quite large dimensions in *L. cordata*, but not in the other species; otherwise the structure is identical. Epidermis and hypoderm are thin-walled, and the cortex which occupies the greater portion of the root is composed of about 5 layers, the cells of which are very large, thin-walled and filled with starch; the intercellular spaces are

narrow. Endodermis is moderately thickened all around, while the pericambium is thin-walled and continuous in *L. cordata.* Five narrow rays of hadrome meet in the center with five relatively wide vessels, and alternate with roundish groups of leptome; the conjunctive tissue is thin-walled and is only to be observed between the vessels, but not in the center of the cylinder. Hyphæ were observed in epidermis, hypoderm and cortex of *L. cordata,* but not in *L. australis.*

Pogonia ophioglossoides Nutt., *P. verticillata* Nutt. and *P. divaricata* R. Br.*

Epidermis is thin-walled and densely covered with hairs in *P. ophioglossoides* and *divaricata,* but less so in the third species. The hypoderm is thin-walled in *P. ophioglossoides,* slightly thickened in the others. The cortex is composed of 6 to 9 layers of thin-walled cells; it is quite open in *P. ophioglossoides,* but very compact in the other species. Starch was only found in *P. divaricata.* Endodermis is thin-walled throughout in *P. ophioglossoides* and *P. divaricata,* but in *P. verticillata* there is one thick-walled cell outside each group of leptome. The thin-walled pericambium is continuous in *P. ophioglossoides,* but is irregularly interrupted by the protohadrome vessels in the two other species. The leptome represents quite large and roundish groups alternating with narrow rays of hadrome; 5 rays were observed in *P. ophioglossoides,* 6 in *P. divaricata* and 8 in the third species; the hadrome extends to the center of the cylinder in *P. ophioglossoides,* but not in the other species. Hyphæ were found in the hypoderm and cortex of all three species.

Calopogon pulchellus R. Br., *C. multiflorus* Lindl. and *C. parviflorus* Lindl.

The root-structure is very uniform in these species and resembles that of *Pogonia,* especially *P. ophioglossoides.* Epidermis and hypoderm are thin-walled in all three species, and the cortex, which, also, is thin-walled, consists of about 8 layers with narrow intercellular spaces; no starch was observed in the cortex. The endodermis is thin-walled throughout, with the spots plainly visible. In the central-cylinder we find a thin-walled pericambium in the two first species, but one moderately thickened in *C. parviflorus;* it is continuous in *C. pulchellus,* but we were unable to trace the exact location of the protohadrome vessels in the other species, whether these had broken through the pericambium or not. Five, and quite broad, hadromatic rays were observed in *C. pulchellus* and *C. parviflorus,* but only three in *C. multiflorus;* the innermost vessels are relatively wide and border on a small, but very distinct, cen-

* Compare this Journal, vol. ix, 1900, p. 13.

tral group of slightly thickened parenchyma. The leptome occurs as small, roundish groups in transverse section. Hyphæ were found in the cortex of *C. multiflorus* and *C. pulchellus*, but none in the third species.

In the following genera of this same type the roots are quite slender, but possess in contradistinction to those described in the preceding, a well developed central parenchyma, which evidently represents a true pith, homologous with the pith of the stem.

Habenaria repens Nutt.

This species is a native of very damp places, and when growing in water the very long roots produce root-shoots. A thin-walled epidermis with few hairs and a hypoderm surround a cortex of about 20 layers of thin-walled cells, of which the outermost 4 constitute a compact and persisting tissue, while the interior 16 are traversed by numerous lacunes from the very wide intercellular spaces; only a little starch, but many bundles of raphides were observed in the cortex, besides hyphæ in the peripheral strata. The cortical parenchyma is, thus, very open, and in several roots, in the entire length of these, a well defined duct was furthermore observed, surrounded by a sheath of very small, thin-walled cells; neither liquid or solid contents were observed in this duct, and its function may evidently be for osmotic exchange of gases.

The endodermis and the continuous pericambium are both thin-walled. In regard to the hadrome and leptome, the former does not occur in rays, but merely as small groups, from 6 to 15, each consisting of a few, 2 to 5, mostly wide vessels, which to a more or less extent alternate with the equally small groups of leptome. The arrangement of the hadrome in proportion to the leptome is somewhat irregular, and we observed several cases where the leptome was really located in front of the hadrome, thus imitating the radial position of these same elements in the stem; in other cases the vessels were on each side surrounded by a group of leptome with the two proto-leptome cells very distinct (fig. 1), as in mestome-bundles of the hadrocentric type, and this position was frequently observed in *H. repens*. The larger portion of the central cylinder consists of a thin-walled pith with deposits of starch.

Arethusa bulbosa L.

The epidermis is thin-walled and densely covered with long hairs; there is, also, an hypoderm, but not easily distinguishable from the cortex. The latter consists of about 6 compact layers with many hyphæ, but without starch. Endodermis and the continuous pericambium are both thin-walled and surround

6 short, but broad groups of rather narrow vessels, alternating with a corresponding number of small groups of leptome, while a pith occupies the greater inner portion of the central-cylinder.

Calypso borealis Salisb.

The structure of the root is almost identical with that of the preceding, and the only differences observed were as follows: the hypoderm is very distinct and the cell-walls are slightly thickened; the cortical parenchyma is a little broader and quite open, the intercellular spaces being relatively wide; the hadrome occurs only as small, 3 to 6, groups of vessels, alternating with the leptome and separated from the center by a large mass of thin-walled pith.

Goodyera pubescens R. Br., *repens* R. Br., *Menziesii* Lindl. and *tesselatum* Lodd.

In respect to the root-structure these species resemble each other very much, and we find in these the same delicate structure of the various tissues, as described above as characteristic of *Arethusa* and *Calypso*. The roots are very hairy, the epidermis, the hypoderm, the cortex, the endodermis and the continuous pericambium are all thin-walled; of these, the cortex consists of about 6 layers in *G. repens* and *tesselatum*, of 8 in *G. pubescens*, and of about 12 in *G. Menziesii;* it is quite compact in all the species except in *G. tesselatum*, in which the intercellular spaces are much wider than in the other species. The hadrome and leptome constitute small groups, when viewed in transverse sections, the former with 4 to 8 vessels in each group, widely separated from the center of the cylinder by a large, starch-bearing and thin-walled pith. The number of hadromatic groups is somewhat variable within the species examined; thus 4 were observed to be characteristic of *G. repens*, 5 of *G. tesselatum* and 6 of the other species. No hyphæ were found in the internal tissues of *G. repens* or *G. tesselatum*, but in the cortex of the others.

Chloræa Austinæ Gray.*

Although the roots of this plant are relatively strong, much more so than in any of the other *Orchideæ* described above, the structure does not reveal any very pronounced mechanical

* The statement by Mr. MacDougal (Bull. Torrey Club 26: 528, 1899) that "this plant is to be added to the list of chlorophylless plants furnished with stomata" is not correct, since we have observed the presence of chlorophyll-grains in the ovary; the guard-cells of the stomata as well as the adjoining epidermis-cells are well supplied with chlorophyll. The description and the figures furnished by this author (l. c.) are altogether very inexact.

equipment. The only tissues which exhibit some thickening are the endodermis and the large, central parenchyma; of these the former is, however, only thick-walled just outside the leptome, and only moderately so. The pith is not thickened very much either, but it occupies such a prominent part, that it necessarily contributes a great deal to the toughness of the root. But the other tissues are thin-walled, and the cortex is composed of 15 compact layers, densely filled with starch and some hyphæ. The pericambium is continuous and surrounds 6 broad rays of hadrome with rather narrow vessels, arranged very regularly in alternation with the large groups of leptome, and border on the very prominent, central pith.

Aplectrum hyemale Nutt.

The densely hairy epidermis, the hypoderm and cortex are all thin-walled, and the last of these consists of about 9 layers with narrow intercellular spaces; no starch or hyphæ were observed, but bundles of raphides. The endodermis and the continuous pericambium are, also, thin-walled and surround 9 broad rays of hadrome, alternating with large, roundish groups of leptome with a central mass of thin-walled pith.

Liparis liliifolia Rich.

The very slender roots show a very feeble structure since all the tissues from epidermis to pith are of a very delicate texture. The epidermis bears many long hairs; the hypoderm is well differentiated from epidermis and cortex by the cells being somewhat stretched radially and almost regularly pentagonal. The cortex consists of about 8 layers and contains a few hyphæ, but no starch; it seems characteristic of certain species of the genus that some of the cells of the cortex exhibit the same spiral thickening of the wall as is well known from the roots of epiphytic genera, a fact that has already been mentioned by Irmisch.* The endodermis is very thin-walled and shows the spots very plainly; the pericambium is continuous and surrounds 12 small groups of hadrome, each with a few vessels, and a corresponding number of small groups of leptome, while a large pith occupies the inner portion of the central-cylinder.

Tipularia discolor Nutt.

As stated above, the roots of this plant show the remarkable structure of possessing a velamen of 3 to 4 layers inside a thin-walled, very hairy epidermis. However this velamen differs from that of the epiphytic *Orchideæ* by lacking the character-

* Beiträge zur Biologie und Morphologie der Orchideen, Leipzig, 1853, p. 34.

istic spiral or simply striate thickening of the cell-walls; otherwise the structure is identical. There, is, furthermore, an exodermis of exactly the same structure as we know from the epiphytic genera. The cortical parenchyma is thin-walled and consists of about 8 layers of roundish cells with narrow intercellular spaces; many hyphæ, but no starch, was observed in this tissue. The endodermis and the continuous pericambium are both thin-walled and surround 5 short rays of hadrome, alternating with 5 small groups of leptome; a pith occupies the inner portion of the central-cylinder.

Bletia verecunda Sw.

In several respects the root-structure of *Bletia* agrees with that of *Tipularia*, but some, and indeed quite important, deviations were noticed. These consist in the more typical development of velamen, the cell-walls of which exhibit the characteristic fine and spiral thickening peculiar to this tissue; moreover by the presence of a double pericambium, which is moderately thickened and to the same extent as the hadrome, thus the position of the proto-hadrome vessels in proportion to the pericambium could not be made out satisfactorily. The hadrome forms 8 short and broad rays alternating with large, roundish groups of leptome, inside of which there is a large, thin-walled pith with intercellular spaces of quite considerable width.

These roots, described above, belong to the first type, all being relatively slender and possessing only one, central-cylinder. In several respects they agree with the second type, in which, however, the dimensions of the roots have increased to such an extent as to deserve the term "tuberous" on account of the much broader zones of the cortex and pith, besides by the larger number of rays or better "groups" of hadrome and leptome.

Type B.

Spiranthes gracilis Big., *S. simplex* Gray, *S. præcox* Wats., *S. Romanzoffiana* Cham., *S. cernua* Rich., *S. cinnabarina* Hemsl. and *S. Asagræi* Schaff.

Even when the roots are quite numerous, as in the last two species, they, nevertheless, retain the same swollen aspect as when they are but few in number or single, as in *S. simplex*. The internal structure is, also, very uniform in these species, and not very different from those described above, but pertaining to other genera.

Common to these species of *Spiranthes* is a thin-walled epidermis with many hairs, besides a hypoderm of one layer, the cells of which are smaller than those of the adjoining cortex.

And as already described by Irmisch (l. c.) as characteristic of the European *S. autumnalis* Rich., the cells of epidermis show the same spiral thickening as we find in the velamen of the epiphytic genera, besides that a similar thickening of the cell-wall is, also, to be observed in the hypoderm of *S. cinnabarina* and *Asagræi.* The cortex is thin-walled and the cells of the innermost layers are very often stretched radially; the number of layers varies somewhat, but is usually about 15, and the contents consist mainly of starch, except in the last two species, where only hyphæ were observed; it seems altogether as if the function of these fleshy roots of *Spiranthes* is to store starch and not water, although the nature of the habitat might suggest that water-reservoirs would be needed. In *S. simplex* and *S. præcox* no hyphæ were observed in any of the tissues, but in the other species the roots proved to be real *mycorhizæ.* As to the innermost layer of the cortex, the endodermis, this seems to be invariably thin-walled in the species examined and shows the Casparyan spots very plainly. The pericambium is represented by only one layer; it is very irregularly interrupted by the proto-hadrome vessels in *S. gracilis*, *S. simplex* and *S. Romanzoffiana*, but in certain roots of the last species it occurred, also, as a continuous ring, the proto-hadrome being located inside. In *S. præcox* the pericambium was found to be continuous near the base of the root, but interrupted near the apex of same. The rays of the hadrome, from 12 to about 20, are very short in all the species and contain but a few vessels, alternating with similarly very small groups of leptome, while the greater portion of the central-cylinder is occupied by a large mass of thin-walled parenchyma, a true pith.

Type C.

The roots of this type are more or less tuberous and contain several cylinders of leptome and hadrome.

Orchis spectabilis L.

If we examine the tuberous root below the hibernating bud, we notice the following structure. Epidermis is thin-walled and there are many root-hairs. Underneath the epidermis is a thin-walled cortex of about 8 layers containing starch and hyphæ, and which borders on 2 mestome-cylinders separated from each other by a few layers of parenchyma, which shows the same structure and contents (starch) as the peripheral cortex. Each mestome-cylinder is surrounded by a thin-walled endodermis, inside of which is a pericambium, which is broken by the proto-hadrome vessels in several places. The hadrome constitutes about 12 irregular and very short rays, which alter-

nate with a corresponding number of leptomatic groups, while a broad pith occupies the inner portion of the cylinder.

The same structure is to be observed in the slender roots of the same rhizome, with the only exception that these contain only one, central mestome-cylinder, the elements of which correspond well with those of the tuberous root, there being about 15 short, hadromatic rays and small groups of leptome surrounding a large, central pith.

Platanthera.

In North America the genus is exceedingly well represented, and occurs with several very distinct types, distinct not only in respect to their flowers, but also in regard to their vegetative organs. The slender, creeping rhizome of *P. rotundifolia* Lindl. is provided with several slender roots, the structure of which is so near that of *P. obtusata* Lindl., that they may be treated together. But in all the other species of the genus examined, the roots, especially the one beneath the hibernating bud, are more or less tuberous, and exhibit a structure that is nearly identical with that of the other secondary, but more slender, roots of the same rhizome.

P. rotundifolia Lindl. and *P. obtusata* Lindl.

Characteristic of the roots of these species is the sparingly hairy epidermis and the lack of any well defined hypoderm. The cortex is thin-walled in both, quite compact in *P. obtusata*, but rather open and not so broad in the other. Large deposits of starch besides hyphæ were noticed in *P. obtusata*, but only hyphæ in *P. rotundifolia*. Two mestome-cylinders of equal diameter are imbedded in the cortex near the center of the root in *P. obtusata*, while there are two large and one much smaller in the other. These mestome-cylinders are, thus, separated from each other by some strata of parenchyma, which may be properly defined as pertaining to the cortex, with which it agrees in regard to structure. Each of these mestome-cylinders has a thin-walled endodermis and pericambium, the latter being continuous in *P. obtusata*. The rays of hadrome (3 in *P. obtusata*, 1 to 5 in *P. rotundifolia*) are very short and consist of but a few vessels, which, together with small groups of leptome, border inward on a thin-walled pith, which is very prominent in *P. rotundifolia*, but rather inconspicuous in the other species.

P. orbiculata (Torr.) and *P. Hookerii* (Torr.).

Habitually these species are very much alike and very distinct from the other North American species of the genus; their root-structure is somewhat different. This difference,

however, depends merely upon the number and relative size of the mestome-cylinders, there being 4, 2 large and 2 small, in *P. orbiculata*, but 8, and all very small, in the other. Besides this variation as to size, their arrangement is, also, quite distinct, since they are located in one ring in *P. orbiculata*, but in two in the other species. Otherwise the structure is identical; the epidermis, hypoderm, cortex, endodermis and pericambium are all thin-walled, and deposits of starch besides raphides were observed in the cortex of *P. orbiculata*, hyphæ, on the other hand, in *P. Hookerii*. Moreover there are noticed 15 short rays of hadrome in the large cylinders of *P. orbiculata*, but only 5 in those of *P. Hookerii*. A central pith was observed in each of these mestome-cylinders and of both species.

The more slender roots show the same structure as the tuberous, described above, but they contain a correspondingly small number of mestome-cylinders, viz: 3 to 4 in *P. Hookerii*, and only 2 in *P. orbiculata*.

In the remaining species of *Platanthera*, which we have examined: *P. dilatata* (Gray), *hyperborea* (Lindl.), *ciliaris* (R. Br.), *psychodes* (Gray), *cristata* (R. Br.) and *tridentata* (Hook.), the roots show an almost identical structure, since the principal difference observable mainly consists in their relative size, their length, thickness and corresponding number of mestome-cylinders, characters of no great importance when we bear in mind the fact, that the tuberous development of such roots is extremely variable and often depending upon certain conditions of the substrate or upon the individual strength of the specimen.

In beginning with the tuberous roots, the epidermis is quite hairy in some species, but merely papillose in others, for instance *P. ciliaris* and *P. psychodes;* this covering with hairs is especially well marked in specimens from *Sphagnum*-bogs. A hypoderm of a single layer is generally present, but seems to lack *P. dilatata*. The cortex is always thin-walled and contains starch, but the number of layers is very variable even in specimens of the same species; hyphæ were observed in all the species except *P. ciliaris*.

The innermost portion of the root is occupied by a large parenchymatic tissue, which, also, contains starch and which is hardly to be distinguished from the cortex; sphærocrystals were observed in great abundance in *P. ciliaris* and *cristata*. The mestome-cylinders occur, sometimes, in several more or less concentric rings, but are mostly somewhat irregularly scattered, especially when their number is very large, as in the thickest roots of *P. ciliaris*. Their number and relative development is variable, but they contain usually from 1 to 5

rays of hadrome with a corresponding number of leptome-groups (fig. 4). The endodermis and pericambium (End. and P. in fig. 4) are constantly thin-walled, and the latter was found to be continuous in some, but interrupted in others of these small mestome-cylinders within the same tuberous root. A very small, central pith was observed in *P. ciliaris* and *cristata*, but not in the others.

If we compare this structure of the tuberous with the slender roots of these same species, there seems to be no other difference than there being a much smaller number of mestome-cylinders in the latter.

Of the three types of roots observable in our terrestrial *Orchideæ*, the third category emphasizes those in which several mestome-cylinders are present instead of but one, and this peculiarity may be briefly described in connection with the anatomical data, mentioned above. The fact that these tuberous roots contain several, isolated cylinders provided with a special endodermis and pericambium, has given rise to various views regarding their morphological identity: whether the "tubers," as they are frequently called, might represent 1) the basal, swollen part of the bud-axis, 2) a single root, 3) a concrescence of several roots or 4) a concrescence of a stem-portion with leaves and roots. Of these the most generally accepted theory is the one which explains the origin of the tuber as being a concrescence of several roots, very ably discussed by Van Tieghem and others.

But the definition tending to explain the tuber as being the result of a concrescence of a stem-portion with leaves and roots, as proposed by Germain de St. Pierre,* has not been approved by others. Nevertheless, as will be shown in the following pages, this definition does not only seem to be well founded, but is, indeed, the only conceivable one, as far as concerns the tuberous body beneath the hibernating bud in North American *Ophrydeæ;* we may illustrate this by the rhizome of *Platanthera dilatata* (fig. 2). The rhizome of this species is relatively slender and the hibernating bud is prominently removed from the mother shoot by the descending stolon (*St.* in fig. 2); the bud itself (*b*) appears as if it were lateral, since the stolon gradually passes over into the long, tuberous body (*r*) underneath the bud, the so-called "tuber" of most authors. The bud, however, is terminal and its apparently lateral position is due to the growth of the stolon, the direction of which is neither horizontal nor vertical, but simply descending. As may be seen from the figure the basal region of the bud with its rudimentary leaves and young roots is located on the upper, the dorsal, face of the stolon.

* Bull. Soc. Bot. de France, vol. 2, p. 659, 1855.

between the lines 4 and 10. Underneath or better "behind" the bud, as the figure shows, is a cylindrical body between the lines 4 and 10, which cannot possibly be defined as representing a stem (stolon) or a root alone, but appears to be a concrescence of both; the result of our anatomical investigation is in favor of this explanation.

In our figure 2, the dotted lines indicate the places where the most important sections have been laid, and the general structure of the rhizome may be briefly described as follows: At its very base (*st.*) the stolon exhibits a structure like that of a typical rhizome with a distinct central-cylinder, surrounded by an endodermis, and with all the minor characters of a stem-portion. But if we examine a section of this same stolon taken a little further down, by the line 2 for instance, the structure is somewhat different, since we observe there two additional, but very small, mestome-cylinders, which are located underneath the central-cylinder; each of these two mestome-cylinders possess an endodermis and a pericambium (End. and P. in fig. 3) and they represent two roots or at least two primordia of such. By continuing our examination of the same rhizome, we observe in section 3 not less than five small mestome-cylinders besides the central, of exactly the same structure as the two described above, and these are very regularly arranged in an arch which is parallel with the lower face of the stolon. At the same time the epidermal structure has become changed, thus the cells on the lower face of the stolon are more or less extended into papillæ and have attained a darker color in contrast to the epidermis of the upper face, which has retained the typical structure of a stem-epidermis. In other words, the stolon has started to become dorsiventral with the development of roots on its ventral face, accompanied by the characteristic epidermal structure.

In following the structure further down to section 4, the large cylinder, formerly central, has become moved nearer the dorsal face of the stolon, and the number of small mestome-cylinders has increased to ten, arranged in two arches parallel with and located near the ventral face. The distinction in regard to the epidermal structure is still more pronounced in this section, and the dorsal epidermis occupies a zone that is much narrower than the ventral. A gradual increase in the number of mestome-cylinders takes place further down, and thirteen were noticed in the sections taken by the lines 5 and 6; furthermore, by 6, the large mestome-cylinder of the stolon is not only still nearer the dorsal face than we observed before, but its pith has become reduced quite considerably in width. And in regard to the bud, the outermost leaf shows here (at 6) a distinct swelling, caused by a cavity at its base. The broad-

est part of the stolon (by 7) contains the bud, and shows, besides, the thirteen small mestome-cylinders, already observed in the section 5, arranged in two arches parallel with the ventral face of the stolon, and with the points of the arches meeting near the central-cylinder of the bud-axis. The large mestome-cylinder is still visible at the line 8 and a little below, but disappears at 9; from here the small cylinders have increased to seventeen, most of which are arranged near the periphery with a few scattered nearer the center. These peripheral mestome-cylinders are quite small and show the same structure as described above; the interior are somewhat larger, but show, nevertheless, an identical structure.

If we now dissect the part of the rhizome located by the line 11, we perceive the structure that has been described so often as characteristic of the "tubers" of *Ophrydeæ:* a large number (23 in this case) of mestome-cylinders, each with a special endodermis and pericambium, and arranged, but not very regularly, in two zones; the distinction between the two epidermal layers (the dorsal and the ventral) has vanished, and the brownish, conical and tuberous body is now covered all around by papillæ and very short root-hairs.

It would thus appear as if at least the upper portion of the tuberous body of the rhizome of *Platanthera dilatata* and the other North American *Ophrydeæ*, which we have examined, is composed of elements pertaining to a stolon, a bud and some roots, instead of being simply a root, a concrescence of several roots or finally a swollen bud-axis. But in offering our support to this explanation, pronounced so many years ago by the French botanist, we are well aware of the difficulty which confronts any investigator who deals with organs that remain in their primordial stage and which are not known to occur otherwise, as the supposed secondary roots of *Ophrydeæ*.

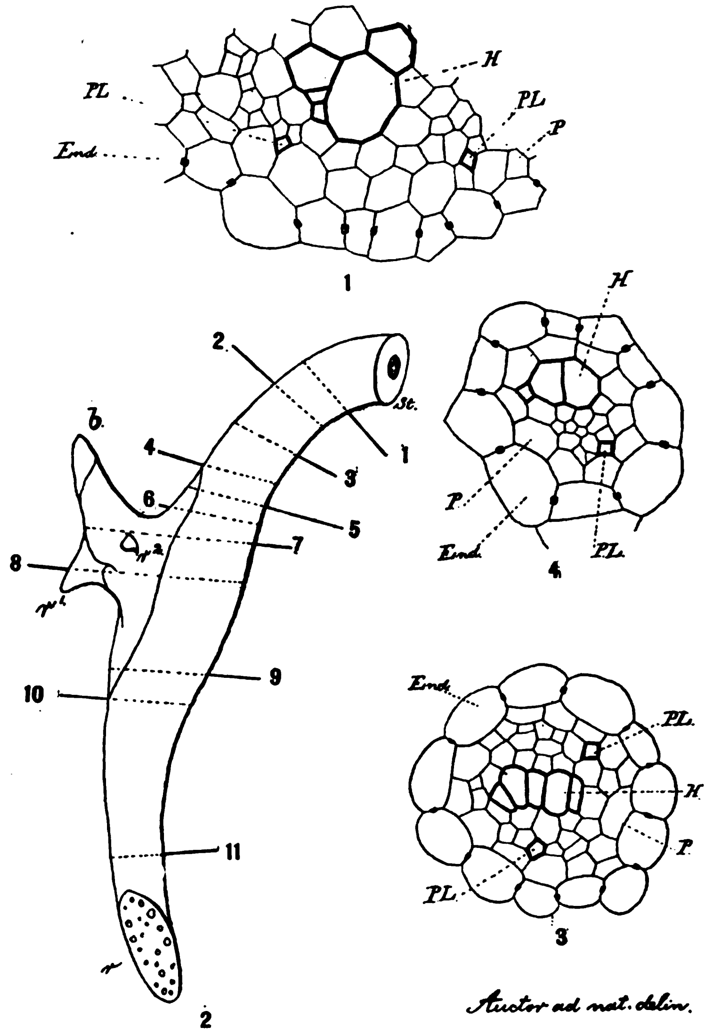
If we had only succeeded in detecting some distinctions in the cortical parenchyma of the stolon, when the supposed roots make their first appearance, so as to be enabled to discriminate between the cortex of the stolon and that of the roots, then there would have been more substantial proof in explaining this organ as a concrescence of roots and stem. But the only distinction which we have noticed depends upon the variation expressed in the epidermal structure, the constant dorsiventrality of the stolon from the first appearance of the secondary roots, and the structure of the small mestome-cylinders being identical with more slender roots of the same species. Of course the word "concrescence" is somewhat misapplied in this particular instance, since these secondary roots have never been observed to be free, not even at the youngest stage of the stolon or of the bud. But otherwise our definition of the

"tuberous body" may from a morphological viewpoint be justifiable, when we compare the rhizome, and especially the arrangement of the roots, with that of other terrestrial *Orchideæ* in which all the roots are free, slender and with only one central-cylinder. In *Arethusa*, for instance, the disposition of the roots is such that if they were united or grown together, they would exhibit exactly the same structure as we have shown being the characteristic of the lower portion of the "tuber" in the *Ophrydeæ*. But the habit of these plants is too distinct to allow us even to imagine ourselves, that such union of the roots in *Arethusa* might be possible.

Summary.

1. A velamen and exodermis is developed in the terrestrial *Tipularia discolor* and *Bletia verecunda.*
2. Some cells of the cortical parenchyma in *Liparis liliifolia* show the same spiral thickening as is known from the epiphytic genera.
3. A similar spiral thickening was observed in the epidermis and hypoderm of several species of *Spiranthes.*
4. The pericambium is composed of two layers in *Bletia verecunda.*
5. The pericambium was observed to be continuous in a number of species pertaining to different genera.
6. The pericambium was observed to be continuous or interrupted in the same root of *Orchis*, *Pogonia verticillata*, various species of *Spiranthes*, etc.
7. Sphærocrystals abound in the inner parenchyma of several species of *Platanthera.*
8. All the roots of *Epidendreæ*, *Neottieæ* and *Cypripedieæ* examined possess only one central-cylinder.
9. A true pith and, sometimes, of quite considerable width was observed in *Tipularia*, *Arethusa*, *Calypso*, *Spiranthes*, *Chloræa*, *Goodyera*, *Habenaria*, *Aplectrum*, *Bletia*, *Liparis*, *Calopogon* and *Cypripedium Californicum.*
10. The cortical parenchyma is traversed by wide lacunes and by a special duct in *Habenaria repens.*
11. The upper portion of the so-called "tuber" of the *Ophrydeæ* examined consists of elements pertaining to a stolon, a bud and some roots; the lower part, on the contrary, of roots alone.
12. The roots of our terrestrial *Orchideæ* very often represent *mycorhizæ*, but not all the roots of the same species, nor of the same specimen.

Brookland, D. C., May, 1904.



EXPLANATION OF FIGURES.

FIGURE 1.—Transverse section of the root of *Habenaria repens*, showing a part of the central-cylinder; *End.* = endodermis; *P.* = pericambium; *P. L.* = proto-leptome; *H* = hadrome. × 320.

FIGURE 2.—Part of stolon with bud and roots of *Platanthera dilatata*, magnified. *b* = apex of the bud; r^1 and r^2 = young roots; *r* = the tuberous root; *st.* = base of stolon. The dotted lines indicate the places where the sections have been laid.

FIGURE 3.—Transverse section of one of the two small mestome-cylinders of the stolon; letters as above. × 320.

FIGURE 4.—Transverse section of a mestome-cylinder from the tuberous root; letters as above. × 320. (Figs. 3 and 4 are both of *Platanthera dilatata*; fig. 3 of a specimen from Vermont, fig. 4 of a specimen from Mt. Elbert in Colorado.)

ART. XXVI.—*A Study of the Structure of Paleozoic Cockroaches, with Descriptions of New Forms from the Coal Measures;* by E. H. SELLARDS.

[Continued from p. 134.]

Etoblattina coriacea sp. nov. Text-figure 29; and Plate I, Figure 11.

Tegmina long, very slender, pointed at the apex, costal border slightly arched, inner border full, very thick; nervation obscure. Subcosta extending to the apex. Cubitus comparatively short, reaching only a little beyond the middle of the wing. Anal area of medium extent; anal veins about ten in number, simple or forked.

The wing is of especial interest, because of its coriaceous texture in which the veins are almost obscured. Only a few terminal branches of the radius and media can be made out. The branches of the subcosta are entirely obscured. A noticeable feature of the wing is the sharp angle made by the anal area.

Formation and Locality.—Upper Coal Measures, Lawrence, Kansas. Type in the University of Kansas collection.

Etoblattina Hilliana ? Plate I, Figure 4.

Scudder, Bull. U. S. Geol. Surv., No. 124, 1895, p. 99, pl. viii, fig. 11.

The wing of Figure 4, Plate I, is doubtfully referred to *E. Hilliana.* The subcostal area is broader than in the type, and the media apparently is not so sinuous.

Formation and Locality.—Coal Measures, Mazon Creek, Illinois.

Spiloblattina.

Scudder, Proc. Acad. Nat. Sci. of Philadelphia, p. 35, 1885; Mem. Boston Soc. Nat. Hist., vol. iv, p. 461, 1890.

The genus *Spiloblattina* was proposed by Scudder to include four species of cockroaches from Fairplay, Colorado. The essential characters of the genus are the wide divergence of the radius and media, and especially of the media and cubitus beyond the middle of the wing, and their subsequent convergence enclosing an elongate or ovate area, the "stigma." Associated with these are other well-defined characters, as the thin tegmina marked with light and dark patches, and dark bands accompanying the veins. The relative distribution of the veins and their areas in this genus are practically the same as in some species of *Etoblattina.* Nevertheless, the *Spiloblattina* group of species, with thin variegated front and hind wings, is evidently a natural one, and without doubt merits generic rank. The sterna of *Spiloblattina* appear from some Kansas

specimens to have a shape different from those of *Etoblattina*, being pointed instead of rounded posteriorly. *Spiloblattina* has not been previously recognized in the Coal Measures, the type having come from deposits which are either Triassic or Permian, but an examination of some Coal-Measure forms from new material convinces the writer that the genus is represented in these formations. In describing the cockroaches from Richmond, Ohio, Professor Scudder noted that some of the species approached closely to *Spiloblattina*, remarking that the disposition of the media and cubitus of *Etoblattina ramosa* is "much after the fashion of *Spiloblattina*." A reëxamination of *Etoblattina maledicta*, a closely related species, leads to its reference in the present paper to *Spiloblattina*.

Spiloblattina maledicta. Plate I, Figures 5, 6, and 10; Text-figures 26 and 27.

Etoblattina maledicta Scudder, Bull. U. S. Geol. Surv., No. 124, p. 83, pl. 6, figs. 1–3, 1895.
Etoblattina benedicta Scudder, ibid., p. 84, pl. 5, figs. 14–15.

Tegmina narrow, two and one-half times as long as broad, costal border slightly arched, inner border nearly straight; tegmina broadest at the extremity of the anal area, apex obtuse. Subcostal area narrow, extending a little beyond the middle of the tegmina; branches mostly simple and oblique. The radius reaches nearly to the apex. The first branch is given off at about the extremity of the basal third, sometimes as early as the end of the basal fourth, and is usually twice forked. Three or four other simple or deeply forked branches pass to the border. The media gives off its first branch somewhat beyond the middle. The main vein and its branches fill the apex. The cubitus varies in extent, either reaching well on to the apical margin, its greatest extent being obtained by an outward curve near the termination, or, lacking the curve, ending short of the apical margin. The first five or six branches are straight, mostly simple, and parallel; the others are more oblique, not uniform in number, curved, and sometimes forked. The anal area extends approximately to the end of the basal fourth, is clearly marked off, and has six or seven mostly simple veins. The main veins of the wing originate close together somewhat above the middle of the base. The veins diverge in the central part, enclosing elongate, light-colored areas. The tegmina are delicate and thin, the veins thin, although appearing heavy in places because of the dark-colored bands accompanying them. The alternate light and dark areas give the wing a striking appearance (Figures 5, 6, Plate I). A dark band extends along the costal border obscuring the tips of the

veins. Similar bands accompany the radius, media, and cubitus. Light areas occur in the interspaces between the main veins as well as between some of the branches. Two conspicuous, large, light spots, with irregular boundaries, occur in the apical part of the wing. The agreement with the types of the species from Richmond, Ohio, is very close. The two light spots on the apical part of the wing are not described for the type, probably because the apex was not well preserved.

In the original description of *E. benedicta*, Scudder expressed doubt as to its specific separation from *E. maledicta*. The differences which seemed to distinguish the two forms were the more arched costal border of *E. benedicta*, the less extent of the cubital area, and the approximation in the point of origin of the two radial branches. More than forty tegmina of this species are at hand for comparison. Camera lucida sketches of numerous wings show that, while those with a short cubitus have, as a rule, a more arched border, there is an almost con-

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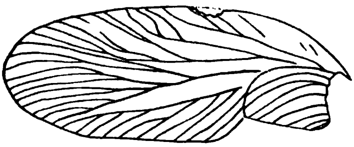

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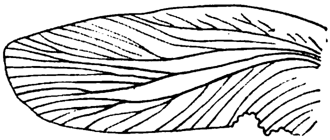

Figures 26, 27.—*Spiloblattina maledicta* Scudder, sp.; illustrating the extremes of variation of the species; ×2. Figure 27, typical wing with extended cubitus; Figure 26, form with arched costal border and short cubitus. Originals in University of Kansas Museum.

tinuous series between, with no break sufficient to serve as a specific character. Figures 26 and 27 show the extreme limits in the extent of the cubitus, the two figures corresponding closely to the type figures of the two forms. In one the cubitus falls decidedly short of the apical margin, while in the other it extends by an outward curve and more numerous branches well on to this border. Other specimens show that the cubitus is variable in extent, and individuals can be found presenting a condition so nearly intermediate that a specific separation can hardly be sustained on this character. The third distinction given, the approximation in the point of origin of the first and second radial branches, is not constant. Occasionally a wing is seen having both a long cubitus and a close approximation in the point of origin of the first and second radial branches.

Hind Wings.—The hind wings are thin, and ovate in shape. The costa is submarginal, straight, and simple. The subcostal

area is narrow, has a few superior oblique short branches, and extends to, or beyond the middle. The radius reaches nearly to the apex and gives off about three oblique, widely forked, or simple branches. The media has four or five superior branches which fill the apex. The cubital area is well developed, the branches oblique, straight, parallel, and mostly simple. The anal area is supported by a few simple radiating veins. Eleven hind wings of this species have been obtained, one in direct connection with the tegmina. The hind wing is of even thinner texture than the front, and is also marked by light and dark areas. A dark area extends along the costal border and dark bands accompany some of the veins.

A few specimens preserving parts of the body, especially the abdomen, show evidence of light and dark areas on the body and are, for this reason, provisionally referred to this species (Figure 22). The abdomen is rather slender; the edges of the terga are of moderate extent. The sterna differ from those of *Etoblattina*, being pointed at the posterior angles. Length of the tegmina, 22 to 25^{mm}; width, 8 to 9^{mm}. Hind wings, 16 to 18^{mm} long; 8 or 9^{mm} wide.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas.

Gerablattina.

Scudder, Mem. Bost. Soc. Nat. Hist., vol. iii., p. 97, 1879.

Gerablattina arcuata sp. nov. Text-figure 1; and Figure 7, Plate I.

Tegmina about twice as long as broad, outer border strongly arched, the apex rounded; inner border nearly straight, interrupted by the anal area. Subcosta arched parallel to the inner border, reaching three-fourths the length of the wing, branches numerous, simple, curved, thin, and parallel. The radius is but slightly developed, branches first beyond the middle of the wing, and falls a little short of the apex. The media, like the radius, occupies a comparatively small area, and remains simple until beyond the middle of the wing, its four simple, oblique branches filling the apex. The cubitus is strongly developed and reaches almost to the apex. The first five branches are simple and nearly straight, the others are more oblique, closer, and curved. The anal area is well marked and has about seven simple veins. In texture and general appearance this species presents considerable similarity to *S. maledicta*. The tegmina, however, are much more strongly arched, and the subcosta has a greater development correlated with a reduction in the radius. Length of the tegmina, 24^{mm}; width, 9^{mm}.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas. Type in Kansas Museum.

Schizoblattina gen. nov.

Small cockroaches; veins of the tegmina numerous, much branched, and united in all parts of the wing by frequent, comparatively strong, cross veins. The main vein trunks are free almost or quite to the base, and show a tendency to disappear by dichotomy. Subcostal area broad at the base, strongly developed, with numerous superior branches. Some of the anal veins end on the anal furrow.

Schizoblattina is apparently not closely related to any described genus. *Neorthoblattina albolineata* Scudder, a small species occurring near Fairplay, Colorado, resembles it in its numerous, much branched veins united by straight, comparatively strong, cross veins. The anal veins also present

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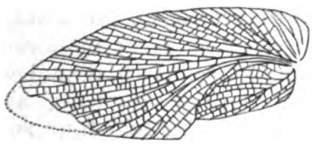

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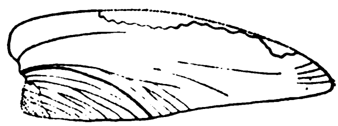

FIGURE 28.—*Schizoblattina multinervia* sp. nov.; × 2.
FIGURE 29.—*Etoblattina coriacea* sp. nov.; × 2. Anal area restored from the obverse side of same specimen. Original in University of Kansas Museum.

the peculiarities of *Schizoblattina*, the first anal giving off several branches which run toward the anal furrow. The other species, including the type of *Neorthoblattina*, have two of the main veins more or less completely amalgamated. That this is also true of *N. albolineata* is not clear from the figure, nor is this point specifically mentioned in the description. It is evident from the peculiar disposition of the anal veins, the occasional cross nervules, and the prolific branching of the veins, that *N. albolineata* is markedly different from the other species of the genus in which it is at present placed, and as far as it is possible to judge from the illustration seems to fall more naturally in *Schizoblattina*.

The geological age of the Fairplay beds, from which *N. albolineata* came, is unsettled, the formation having been referred both to the Triassic and to the Permian.

Schizoblattina multinervia sp. nov. Text-figure 28.

This Journal, vol. xv, pl. vii, fig. 6, April, 1903.

Tegmina small, a little more than twice as long as broad. Costal and inner borders both arched, sloping gradually and equally to the apex, which is placed about the middle of the

wing. Tegmina strong, supported by numerous close branches with frequent, comparatively strong, cross veins in all parts of the wing. Subcostal area broad at the base, triangular, extending a little beyond the middle of the wing. The branches are numerous, once or twice forked, the first arising from near the base and the distal more oblique than the proximal. The radius is clearly distinct from the subcosta. The first branch is given off about the end of the basal fourth of the wing and is two or three times branched. The main vein runs in a sinuous course, reaching the costal border a little short of the apex, giving off three or four oblique, once or twice forked branches. The media is close to, but distinct from, the radius. It dichotomizes first beyond the first branch of the radius, near the end of the basal fourth of the wing. Both branches dichotomize frequently, the numerous divisions filling the distal third of the inner margin and the apex. The cubitus divides early. The branches, dichotomizing two or three times, fill the middle third of the inner margin. The anal area is of moderate extent. The first anal vein gives off five superior branches. The first and second of these, arising close to the base, are once forked, the other three being simple. The first four run toward the anal furrow, the fifth turns down parallel with the furrow and passes to the inner border. A forked inferior branch is also given off from the first anal. The greater part of the area is thus occupied by the first anal and its branches. Three other short curved veins can be seen close to the inner border. Length of tegmina, 17^{mm}; breadth, 7^{mm}.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas. Type in the writer's collection.

Archoblattina.

Megablattina, Sellards (non Brongniart). this Journal, vol. xv, p. 312, April, 1903.
*Archoblattina**, Sellards, ibid., vol. xv, p. 488, June, 1903.

Large cockroaches; body bulky, abdomen broad and fleshy; pronotum large, longer than broad, approaching a rectangular form, truncated or slightly emarginate in front, emarginate at the sides, broadest and rounded behind; front and hind wings large, overlapping the abdomen.

Archoblattina Beecheri. Text-figures 30, 31, and 32.

Megablattina Beecheri Sellards, this Journal, vol. xv, p. 312, April, 1903, pl. viii.
Mylacridæ sp.? Scudder, Bull. U. S. Geol. Surv., No. 124, p. 55, 1895, pl. ii, fig. 4.
Blattina sp.? ibid., p. 142, pl. x, fig. 16.

Tegmina large, about three times as long as broad, costal border arched only very slightly, inner border nearly straight.

* *αρχων*, prince.

Subcosta curved parallel with the costal border and extending two-thirds the length of the wing, giving off numerous simple or compound branches. Radius forked about one centimeter from the base, and consisting of a few long, nearly parallel branches, which strike the border near, but above, the apex. The media forks first near the middle of the wing; the median

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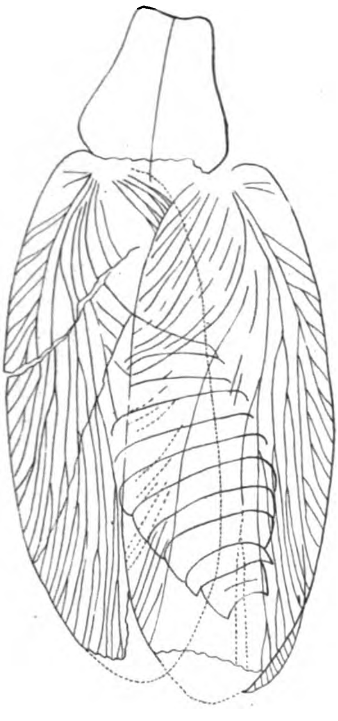

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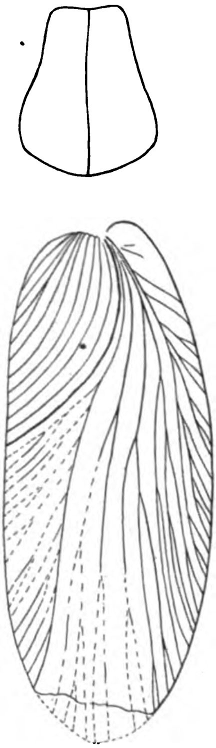


Figure 30.—*Archoblattina Beecheri* Sellards ; type specimen ; dorsal view.
Figure 31.—The same ; pronotum and wing partly reconstructed.
Original in Yale University Museum.
Both figures are natural size.

area is narrow, consisting of a few long veins running to about the apex. The cubitus, although imperfectly preserved in the specimen at hand, is evidently of great extent, apparently reaching to, or beyond, the inner angle of the wing, and giving off numerous inferior branches. The anal area is of medium extent, strongly marked off by a prominent furrow, and consists of nine or ten simple or forked veins.

32

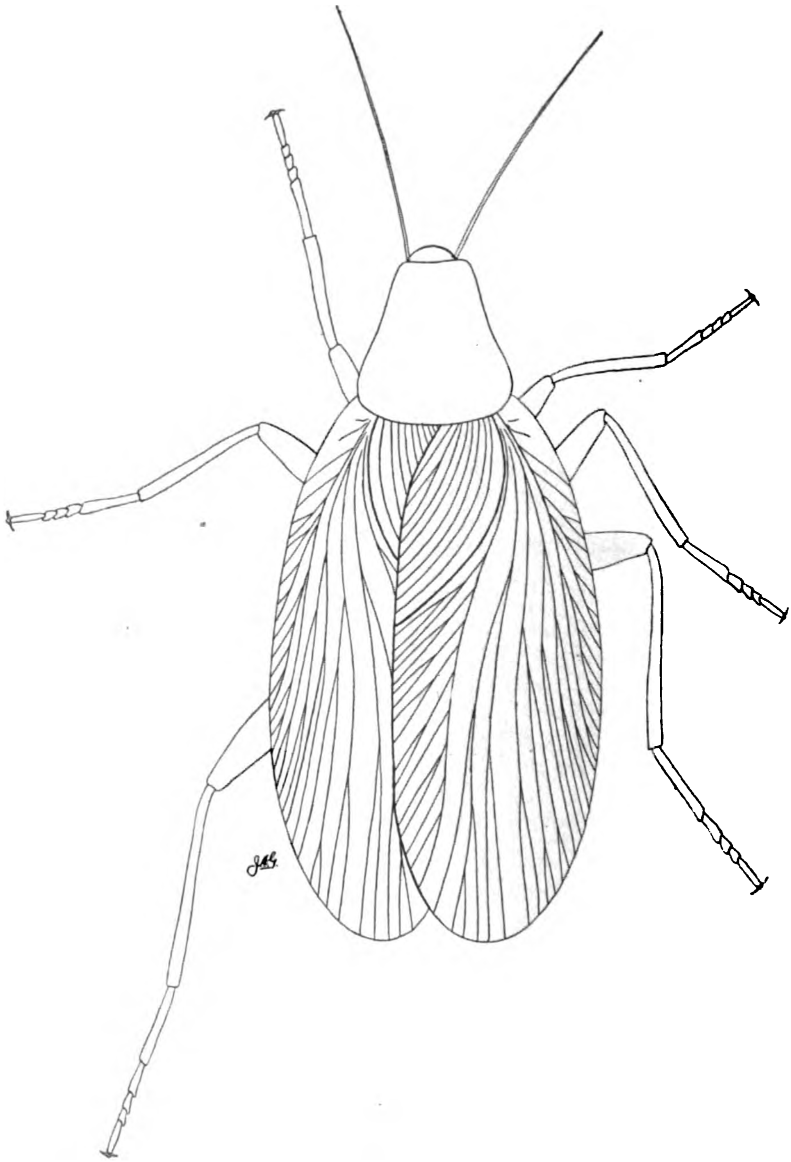


Figure 32.—Restoration of *Archoblattina Beecheri* Sellards; natural size.

The most distinctive character of this genus of huge cockroaches is the large, nearly rectangular pronotum, broadest at the base, and with sides and anterior border slightly emarginate. The abdomen is seen indistinctly through the wings; it is large and indicates a bulky body. The length from the front of the pronotum to the tip of the wing is 9^{cm}, making this probably the largest cockroach known. The tips only of the hind wings are seen. Apparently they are of about the same extent as the front wings. The large hind wing from the same locality, described as *Blattina* sp. by Scudder, is here provisionally referred to this species. If this reference is correct, the hind wings are very broad, with much rounded inner border.

The half-tone illustration accompanying the original description of the species was made from the mould of the dorsal surface. The figure given here is taken from the counterpart, in which the outline of the abdomen is more distinct. The two pairs of wings considerably overlap the broad abdomen. The life-size restoration is made from the specimen figured. The antennæ and legs are reconstructed from related genera. The position adopted is based upon an instantaneous photograph taken for this purpose, of the common oriental cockroach, while running. As represented in the restoration the first leg on the left side has just been thrown out in front, the second on the right side is in motion, while the third on the left is just ready to be drawn forward. The other set of three are, for the instant, supporting the weight of the body. It is not known whether the tibiæ of the genus are supplied with spines. These features are, therefore, omitted from the restoration (Figure 32).

Formation and Locality.—Coal Measures, Mazon Creek, Illinois. Type in the Yale University Museum.

Hind Wings not in connection with Front Wings.

The difficulties of nomenclature met with in the systematic treatment of the nymphs of fossil cockroaches are again encountered in dealing with such detached hind wings as lack sufficient characters to identify them with their respective front wings. Several well-marked types of hind wings, presumably representing at least as many species, have been recognized in the collections studied, three of which can be identified with the front wings. The hind wings of *Spiloblattina maledicta* have been described above in connection with the tegmina of that species. The hind wing of *Promylacris rigida* (Figure 36) is taken from the type specimen (No. 38045, U. S. Nat. Mus.). It is of special interest as revealing the form and

venation of the hind wing of the Mylacridæ. The wing is narrowed at the base, the costal border being nearly straight or a little concave at this point. The inner border although not complete is evidently rounded, and the apex obtuse. The most interesting feature of the wing is the position of the costa, which is some distance from the margin and gives off a thin superior branch. The subcosta is a stronger vein, but has only one offshoot. The radius is more developed; it divides into two nearly equal parts near the base, both of which are compound, the ultimate divisions supplying the border from the termination of the costa to the apex. The media also divides into two compound, nearly equal divisions close to the base, the branches running to the apical border. The cubitus gives off a few inferior branches which curve regularly to the border. Only a small part of the anal area is preserved. The wing just described is the left wing of the specimen. The costa of the right has two thin superior branches. The radius differs in the detail of its branching; the first and second offshoots of the lower division of the main vein are united for a short distance at their base, making a single forked branch instead of two simple branches. Length of the wing, 24 or 25^{mm}; breadth, 11 or 12^{mm}.

Formation and Locality.—Middle or Lower Coal Measures, Mazon Creek, Illinois.

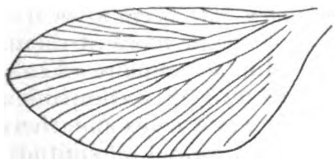
The type of hind wing most abundant in the Lawrence Shales is that illustrated in Figure 33. There are nine specimens of the species, all conforming closely to a common type. The wings are uniformly ovate. The inner border is full and rounded. The costa is straight, simple, and reaches about one-fourth the length of the wing. The subcostal area is, as usual, in the hind wing, narrow and of slight extent. A few thin superior branches are given off from the main vein beyond the extremity of the costa. The radial area reaches nearly to the apex and has about four forked branches. The median area is large and fills the apex. The cubitus has several very oblique, simple, parallel branches. The few anal veins are parallel and usually simple, longer and more curved than in *Spiloblattina maledicta.* The wings are all of a brownish color. The species doubtless belongs to the genus *Etoblattina*, as the wings are of the ovate type, with full inner borders, thus resembling other species of that genus. Length of wing, 18 to 20^{mm}; width, 9 to 11^{mm}.

Formation and Locality.—Upper Coal Measures, Lawrence, Kansas.

Another species, the generic reference of which is doubtful, is represented by three specimens. The wing is contracted at the base and has an unusually narrow attachment. The costal

border near the base is quite concave, and the wing otherwise shows evidence of a specialized condition. The subcosta, radius, and media are united for some distance from the base. The first to separate is the media, which occupies a comparatively narrow area, branching first about the middle of the wing, its divisions running to the apex. The radius then separates from the subcosta 5 or 6^{mm} from the base, and reaches almost to the apex. The subcosta has only a few thin superior branches. The cubitus has the typical, very oblique, mostly simple veins. The anal area is long and has a few curved, forked, and rather loosely placed veins. Length, about 17^{mm}; width, 9 or 10^{mm}. Figures 34 and 35.

33



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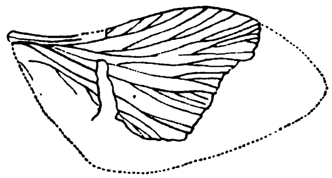

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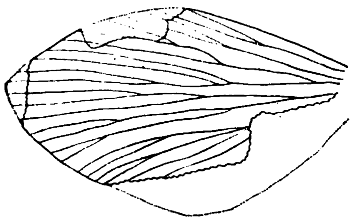

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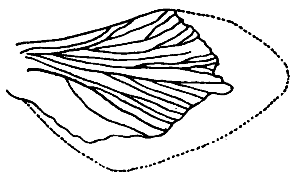


FIGURES 33–36.—Hind wings. Figure 33, *Etoblattina* sp.; Figures 34 and 35, undetermined; Figure 36, *Promylacris rigida*, from the type specimen; all twice natural size. Originals of Figures 33 and 35 in University of Kansas Museum; of Figure 36 in the National Museum.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas. Types in the University of Kansas collection.

General Considerations.

The cockroaches have proved themselves a remarkably persistent type. They are known to range in time from the Middle Carboniferous to the present, and doubtless took their origin somewhat earlier. The Carboniferous representatives, as described above, were in many respects much like their modern descendants. The body had, as Scudder has well said, essentially the same shape.. The legs indicate the same habit

of locomotion. The pronotum was as characteristic a feature of the Carboniferous as of the recent cockroaches, and formed quite as secure a protection for the small inflexed head. The front wing had a similar arched form, and the anal area was as well defined. Nevertheless, a closer inspection of the successive types reveals the fact that the group has by no means remained stationary throughout its long existence, but, like other organisms, is subject to the laws of advance and specialization. As will be gathered from what has preceded, the most marked changes from paleozoic to recent times have been in the structure of the framework of the front and hind wings, as well as in the abdomen and the ovipositors, and are thus in accordance with the general rule of change from the simple to the more complex, or from the generalized to the more specialized condition. In the front wings the tendency has been toward a reduction of the main veins by fusion of one or more of them. The main veins of both wings have approached more closely to the costal border. These changes have been accompanied by a less uniform development of the main veins and their branching systems. The hind wing has acquired a longitudinal, and in a few genera a transverse fold, and in most genera a fan-like plaiting of the expanded anal area. Numerous and comparatively strong cross veins, rare in the front wings, and unknown in the hind wings of paleozoic forms, have now become very commonly developed in both wings. Not only have both wings departed more widely from the primitive type, but differentiation between the front and hind wings has increased as well.* The front wings have become, as a rule, more resistant, although there were species in the Carboniferous with wings more opaque than some of the thin-winged living species. Important changes have occurred in the abdomen. The terga and sterna have been modified, tending toward a reduction in the number of abdominal segments. The genital pouch has been perfected, and the ovipositors have become reduced and adapted to perform a specialized function.

The division into coördinate groups, based originally on the differences in the venation of the front wings, was strengthened by the discovery of a well-developed ovipositor in paleozoic forms. More complete knowledge of the second pair of wings brings out additional distinctive characters. In the meantime, forms more or less intermediate are coming to light, and it may be confidently expected that the late paleozoic and early mesozoic will in time yield other intermediate forms. The exact point of disappearance of the Paleoblattidæ and origin of the Blattidæ is at present unknown. The geological age of the Fairplay deposits in South Park, Colorado, which contain the latest forms of the one in association with the earliest of the other,

* See also, Scudder, Mem. Boston Soc. Nat. Hist., vol. iii, p. 31, 1885.

has not been entirely established. Lesquereux, on the evidence of the flora, referred the deposits unhesitatingly to the Permian. Scudder, from a study of the insects, insisted on the Triassic age of the beds. The plants were found to represent several characteristic paleozoic genera. The insects belonged to eight genera, seven of which were cockroaches. Three of the cockroach genera were otherwise known only in the paleozoic, the remaining genera were new and at that time peculiar to the locality. It may not be out of place to add in this connection that the range of cockroach genera, as understood at the present time, is much less contradictory to the evidence drawn from the plants than was supposed when the papers in question were written. Five of these seven cockroach genera are now known to occur in the Coal Measures and Permian, leaving only two peculiar to the Fairplay locality and of Triassic affinity. In view of the occurrence as low down as the Coal Measures of the advanced genus *Schizoblattina*, described above, it would not be surprising to find true Blattidæ as early at least as the Permian, and should the fossil here tentatively identified as an egg case, prove to be such, it must be accepted as evidence of the existence of Blattidæ along with Paleoblattidæ as early even as the Upper Coal Measures. Of the Paleoblattidæ, the Mylacridæ will doubtless be found the older. The broad pronotum with but slightly rounded posterior border, the greater distance of the subcosta from the costal border, and the presence of a branched submarginal costa in the hind wing, all indicate the earlier position of this tribe. The Blattinariæ, on the contrary, are more diversified, continue later, and lead up to more advanced types.

In the course of their development, the cockroaches afford illustration of laws of evolution which may be summarized under the headings: Specialization by reduction; parallel evolution; mechanical principle of evolution; and recapitulation of ancestral characters.

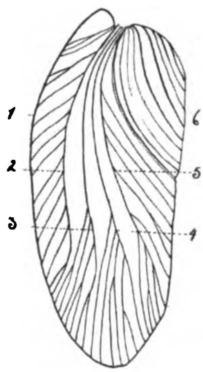
Specialization by Reduction.—The long ovipositor of early cockroaches seems to indicate that a well-developed ovipositor is a primitive character in the Orthoptera, its reduction in the modern Blattidæ being an expression, like the peculiar egg case and genital pouch, of a specialized condition of the external genital organs. In this respect the Gryllidæ and Locustidæ present, no doubt, a closer approximation to the early condition than do the cockroaches, although on the whole the latter seem to be the more generalized. The more or less complete fusion of two or more of the main veins at their base or throughout a part of their course appears to be a second illustration of the law of specialization by reduction.

Parallel Evolution in the Orthoptera.—The plication, so constant a feature in the hind wings of modern Orthoptera, is,

as Scudder maintained, a comparatively recent acquisition. It is to be noted that the plaiting as well as the fold of the hind wing of cockroaches developed subsequent to the differentiation of these insects as a distinct phylum. A comparatively broad anal expanse was, however, common to the early Orthoptera, but the plaiting itself has originated independently in more than one division of the order. The same is true of cross veins. It is probable that at the time cockroaches were differentiated, well-marked cross veins were entirely lacking. Now, on the contrary, cross veins are numerous and not unlike those of other Orthoptera.

Mechanical Principle.—The plications are doubtless developed largely in response to mechanical need. Mechanical principles seem also to have had an influence in developing cross veins.* The interchange of the circulating fluids of the wing, tending to follow within established paths, probably also influenced the development of cross veins.

1



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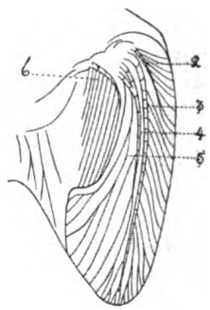


FIGURE 1.—*Gerablattina arcuata* Sellards; illustrating venation of a typical Carboniferous adult cockroach wing.
FIGURE 37.—Wing of a recent nymph; showing venation. (After Packard.)

Recapitulation of Ancestral Characters.—The recurrence during the ontogeny of the individual of characteristics found in the adult condition of earlier representatives of the phylum is familiar to the student of any group. The insects are not an exception to the general rule. In the accompanying figures the nervation of the wing of a modern nymph cockroach is brought into comparison with a typical Carboniferous adult.

* It is interesting to notice an analogous progressive evolution in the vegetable kingdom. The Carboniferous flora contains a great majority of simple veined leaves, while at the present time netted-veined leaves predominate. In the case of plants, both mechanical and physiological factors have doubtless operated.

Homologous veins bear the same number. The close similarity is very apparent. The modern cockroaches thus present in their ontogeny an interesting illustration of the recapitulation of ancestral characters.

EXPLANATION OF PLATE I.

FIGURE 1.—*Mylacris elongata* Scudder. An adult, slightly enlarged. Same specimen as illustrated by Text-figure 8. The head projects in front of the pronotum. The abdomen is noticeably short in comparison with the thorax and long wings.

FIGURE 2.—*Etoblattina mazona* Scudder. Nymph with ovipositor preserved. Same specimen as Text-figure 13.

FIGURE 3.—*Mylacris* (*Dipeltis*) *diplodiscus* Packard, sp. Type specimen. The head projects from beneath the pronotum. The impressions of the first pair of legs are indistinctly seen through the integument. The femora of the second pair of legs can be detected in the photograph. For a line drawing of the specimen, see Text figure 4.

FIGURE 4.—*Etoblattina Hilliana?* Scudder.

FIGURE 5.—*Spiloblattina maledicta* Scudder. sp. The wing shown in this photograph, also in Text-figure 26, is of the form or variety of the species with arched costal border and short cubital area.

FIGURE 6.—*Spiloblattina maledicta* Scudder, sp. Typical wing of the species having slightly arched costal border correlated with great extent of the cubitus. Same as Text-figure 27.

FIGURE 7.—*Gerablattina arcuata* sp. nov. Type specimen. The wing, as the photograph shows, has light and dark areas similar to those of *Spiloblattina*, to which genus possibly the species should be referred. The same specimen is illustrated by Text-figure 1.

FIGURES 8, 9.—*Etoblattina* sp. Detached hind wings. Same specimens as Text-figures 34 and 35.

FIGURE 10.—*Spiloblattina maledicta* Scudder, sp. The hind wing is of thinner texture and has color area similar to those of the front wing.

FIGURE 11.—*Etoblattina coriacea* sp. nov. Same as Text-figure 29.

Figure 1 is but slightly enlarged; Figure 3 is a little less than twice natural size; all others are enlarged approximately two and one-half diameters.

Figures 1-4, from the Coal Measures of Mazon Creek, Illinois; all others from the Upper Coal Measures of Lawrence, Kansas.

Originals of Figures 1, 2, and 4, in the Yale University Museum; of Figure 3, in the National Museum; all others, in the University of Kansas Museum.

Art. XXVII.—*Electrotropism of Roots;* by Amon B. Plowman. (With Plates IX and X.)

In a brief report published in this Journal last month, the writer gave the more important results of a series of experiments in the field indicated by the above title. These observations extend over a period of more than two years, and have been carried on as a part of a general study of the electrical relations of plants, at the Memorial Research Laboratory of Harvard University. As indicated in the preliminary paper, this particular phase of the work has had for its object the explanation of the behavior of roots growing in the presence of an electrical current.

The general fact of galvanotropic response in roots was established in 1882 by the careful studies of Elfving,* who found that the roots of young seedlings growing in spring-water through which a current of electricity was flowing, almost invariably turned, after a little time, toward the positive electrode. Elfving modified his experiment by using from one to six Leclanché cells in his battery; by varying the distance between electrodes from $2{\cdot}5^{cm}$ to 15^{cm}; by the use of zinc, copper, platinum, and carbon electrodes; and by a study of various plants, including species of *Vicia*, *Zea*, *Secale*, *Hordeum*, *Cannabis*, *Ricinus*, *Cucurbita*, *Tropaeolum*, *Convolvulus*, *Cynara*, *Helianthus*, and several others. He found that throughout all these variations in conditions the results remained practically constant in kind, the roots always turning, sooner or later, toward the positive pole. He observed, also, that the roots were invariably killed by the prolonged action of the current from even a single Leclanché cell.

By way of explanation of his results, Elfving showed that the elongation of a root in the presence of an electric current is approximately only half as great in a period of 12 hours as is that of a similar root growing under normal conditions for the same length of time. Hence it was evident that growth was retarded by the electric current, and the greater retardation on one side than the other of the root was attributed to some unknown property of the root itself. This view of the matter was apparently fully justified by certain results obtained by Elfving in his trials with seedlings of *Brassica* and *Raphanus*. In the former the majority of the roots turned toward the negative pole, while in the latter there was no well defined response in either direction. This would indicate a specific difference which could be attributed only to the protoplasm itself, and it was upon this difference that Elfving proposed to separate plants into two groups, the one positively galvanotropic, the

* Bot. Zeit., 1882.

other negatively galvanotropic. It should be stated, however, that in the earlier part of his paper Elfving observes that galvanotropism is not to be considered a biological phenomenon of the same order as heliotropism, geotropism, and most other common paratonic responses. In accounting for the invariably fatal effects of a long-continued current, Elfving offers the suggestion that the electrolyte is probably rendered toxic by the formation of poisonous compounds at the surface of the electrode.

While Elfving's study of this subject was quite complete and his methods were in general above question, it has seemed desirable not only to repeat his work, but to extend it in a number of lines, in order, if possible, to arrive at some more satisfactory explanation of the results obtained.

The electrical equipment used for these and related studies consists of a battery of "Excelo" cells, a small direct-current dynamo, the 500-volt city power current, and various resistances, rheostats, and measuring instruments. The "Excelo" cell is a combination of the principles of the Daniell cell and the "gravity" cell. This cell is very satisfactory for closed-circuit work, since it maintains a practically constant potential for days or even weeks, especially when only a fraction of the available amperage is used. The dynamo is of the General Electric type, driven by a General Electric 500-volt direct-current motor. The dynamo is rated at 2·5 kw. capacity, at a voltage ranging from 75 to 125 at normal speed, controlled by a field rheostat. A speed-rheostat on the motor permits a considerably wider range of voltage in the dynamo. The 500-volt power-current itself is available for experimental work, through a series of resistances and rheostats. Among the measuring instruments are included a watt-meter, volt-meters, ammeters and galvanometers, one of which is sensitive to 10^{-6} volt. It is possible to obtain from this equipment a fairly complete gradation of measured initial potentials from 500 volts down to 10^{-6} volt.

However, it is not always sufficiently explicit to state merely the difference in potential between the terminal electrodes, since the amount of the current, which is the essential thing, depends quite as much upon the form and conductivity of the electrolyte as upon the initial potential-difference between the electrodes. In other words, it is the density of the current which is of importance in our present investigation. Current density has been variously defined by different authorities,* but it is sufficiently definite for our purpose to consider current

* A. Gray, "Absolute Measurements in Electricity and Magnetism," p. 7, 1888. Oliver J. Lodge, "Modern Views of Electricity," p. 69. 1889. W. E. Ayrton, "Practical Electricity," p. 117, 1887. Clerk Maxwell, "Electricity and Magnetism," § 64, 1881.

density as the amount of current passing a unit cross-section of the conductor in unit time. This, in any case, will evidently depend upon the E.M.F. of the current, the conductivity of the conductor, and upon its sectional area and the distance between electrodes. The unit of current density is the milli-ampere, and the current is of unit density when the conditions of the circuit are such that one milli-ampere of current passes 1^{cm^2} of sectional area of the conductor in one second.

The general method of experimentation has been similar to that followed by Elfving. Fig. 1 (Plate IX) shows one of the vessels used in subjecting roots of seedlings to the action of an electric current. Internally this vessel measures about 5^{cm} wide, 15^{cm} long, and 18^{cm} deep. When in use the cubette is wrapped with black paper in order to protect the roots from the influence of light. In the majority of cases the electrolyte employed has been ordinary tap-water, though as one phase of the study, dilute solutions of a great variety of substances were used. Since the products resulting from the electrolysis of common metallic electrodes such as copper, zinc, tin, etc., are usually highly injurious to plants, it was found necessary to use electrodes of platinum or carbon. The latter material has proved to be entirely satisfactory, and it is to be recommended for its cheapness and convenience. In the small vessel shown in fig. 1, the electrodes are "Electra" arc-lamp carbons, $\frac{3}{8}''$ x $7''$, fitted with binding-posts for connecting the wires. In a larger vessel plate-carbon electrodes were used. These were of high-grade carbon, $\cdot 6^{cm}$ x 4^{cm} x 15^{cm}, each with a binding-screw. It has been shown by repeated experiments that the product of electrolytic decomposition of these carbons is perfectly harmless to plants, even when present in sufficient amount to render the electrolyte quite black.

The seedlings are suspended by glass hooks passing through a sheet of cork which serves as a cover for the vessel. In this way perfect insulation is secured, thereby preventing any passage of current through the root in the direction of its longer axis.

The seeds are first germinated in moist sphagnum, and when the radicles have reached a length of 2^{cm} to 4^{cm}, the seedlings are attached to the glass hooks with their roots pointing directly downward and dipping a short distance into the water in the jar. If left to grow normally in such a situation, some roots will grow directly toward the bottom, while others bend about in a more or less tortuous path. It is a well-known fact that different species of plants show characteristic behavior in this respect. Thus *Pisum sativum*, many varieties of *Zea mais*, and various other plants develop quite crooked roots when grown in water, while other varieties of *Zea mais*, *Lupinus albus*, *Hyacinthus orientalis*, etc., grow long straight roots under these circumstances.

However, if a current of electricity be passed through the

water in which these roots are growing, they almost without exception turn, sooner or later, toward the positive pole. The time required for this reaction depends upon the kind of plant, as well as upon the density of the current. In a uniform current, those plants which show most rapid normal growth of the roots are the ones which show a typical curvature most quickly. For any given kind of root there is a maximum current density at which the curvature is produced most rapidly, while a weaker current requires a longer time to bring about the same results. On the other hand, if the current density be raised even slightly above the specific maximum, the roots are killed before curvature can take place. As is to be expected, this specific maximum differs considerably in different plants, and also for roots of different degrees of maturity in the same plant. Thus the maximum effect is produced in a radicle 2^{cm} long of *Lupinus albus* by a current density of about 1 milli-ampere, while a similar root of *Zea mais* reacts most rapidly in a current of 1·5 milli-amperes. For roots which have reached a length of 12^{cm} or 15^{cm} the maximum current density is less than for the shorter roots, being about ·8 milli-ampere for *Lupinus* and 1 milli-ampere for *Zea;* and the maximum curvature is less rapid than in the case of young roots.

The abruptness of the curvature is dependent chiefly upon the kind of plant and the vigor of the root, but, other things being equal, it appears that the sharpest curves are formed in a current considerably below the specific maximum density. It frequently happens that roots of *Zea mais* are curved through an angle of 90° in a length of 1^{cm} or less, and very young radicles of *Lupinus albus* have been bent through a right angle in a length hardly exceeding twice the diameter of the organ at the middle point of the curve.

Fig. 2 represents a number of young seedlings of various size of *Zea mais*, after being exposed for one hour to a current density of 1·2 milli-amperes. The sharpest curvature in this case is shown by the shortest of the radicles, while the longer ones show a more gradual bending. If a weak current is kept on such seedlings as these for several hours, it is found that the majority of the roots continue to grow horizontally toward the positive pole. The maximum current density invariably kills the roots in a short time, as was observed by Elfving, but it has been found possible to adjust the current to such a strength as not to kill the roots and yet to hold them to their horizontal course against their normal geotropic tendency.

On the other hand, if the current is turned off after an hour, and the seedlings are left in the water for a time, we often obtain such results as those shown in fig. 3. Here most of the roots have continued to curve, in some cases forming complete coils. It has often happened that roots which have been less seriously affected than those shown in fig. 2 will, when removed

from the action of the current, bend downward again near the tip, forming a double curve, and continuing to grow in an altogether normal way again. In such cases there is always developed a conspicuous enlargement of the root at the second, or lower, curve, and a constriction at the first, or upper, one. This constriction is always in the form of a flattening of the concave side of the curve.

The location of the greatest curvature in the root is, as Elfving observed, at the point of most rapid normal elongation. It should be added, however, that the sharpest part of the curve is at the point of most rapid elongation at the time when the current is first turned on. This fact is most strikingly evident in the case of very vigorous roots exposed to a rather weak current. In long roots which are exposed for their whole length to the current, there is but little curvature in the piliferous zone. Hence it appears that the curvature is dependent upon active growth of the cells.

When the seedlings are suspended so that the root-tips just touch the water in the jar, the curvatures are usually different from those developed when the roots are wholly submerged, and the reaction varies more noticeably with change in amount of current. For example, if seedlings of *Lupinus albus* are arranged with roots dipping 1^{mm} or less into the water, and a very strong current, say 10 milli-amperes, is passed for a few minutes, the root-tips soon curl to such an extent as to be lifted out of the water. In a few instances the roots have continued to grow horizontally for several millimeters just above the surface of the water, and toward the positive pole, but they are usually killed at once by a current of this density. With a very weak current the roots do not commonly begin to curve perceptibly until the zone of most rapid elongation reaches the surface of the water, when a prompt response occurs, just as in the case of wholly submerged roots.

When the seedlings are placed with their roots horizontally, or parallel to the path of the current, those which point toward the positive pole continue to grow in that direction, contrary to the influence of the force of gravity, so long as the current is comparatively weak. A stronger current quickly kills these roots, though without producing any curvature in them. The roots pointing toward the negative pole usually bend downward in a perfectly normal manner for a little time, then the curvature becomes very abrupt, and the tips are turned back toward the positive pole. If the current is turned off at this stage, the roots sometimes continue to bend, forming a complete coil, and then growing downward again. It usually happens, however, that the seedlings are killed by this treatment.

Elfving has shown that when an electric current is passed upward through a root the cells are quickly killed, while other roots transmitting a similar current downward are not seriously

affected, even after several hours. This experiment was repeated by suspending two seedlings by hooks of platinum wire, with the roots dipping several millimeters into a vessel of water. The platinum wires are connected through a resistance with the battery, making a circuit downward through the first root, and upward through the second. Under these conditions a ·1 milli-ampere current killed the second root in twelve hours, while the first was not apparently affected. When a ·5 milli-ampere current was passed through the roots for half an hour and then turned off, the second root was greatly checked in its growth, and after a few hours it showed a pronounced bending toward the other root. In every case the prolonged passage of even a very weak current caused a loss of turgor in the parts of the first seedling in the region of the platinum contact, even when the root itself was unaffected.

In comparing the results of these studies with those given by Elfving, it appears that there is substantial agreement in the general fact of response curvatures. The plants examined include practically all those enumerated by Elfving, with the addition of species of *Lupinus*, *Linum*, *Fagopyrum*, *Milium*, *Allium*, and *Hyacinthus*. However, it has been shown that the passage of an electric current through water in which seedlings are growing is not necessarily fatal to the plants, as asserted by Elfving, but that the current may be so weak as not to kill the roots and yet cause them to grow horizontally toward the positive pole.

Moreover, the so-called "negative galvanotropism" mentioned by Elfving does not seem to be a constant property of any species thus far studied. That the usual curvature toward the positive pole is less pronounced and less constant in some species than in others, can not be denied. However, the reverse curvature has not been found to be constant in any case, and even in the most doubtful species it has been possible, by varying the density and time of action of the current, to produce the normal curvature in a majority of the roots.

That Elfving was justified in concluding that galvanotropism is not of the same order of phenomena as heliotropism, geotropism, hydrotropism, etc., is made apparent by the facts just pointed out. The great rapidity of the reaction under certain conditions, and the fact that all but extremely weak currents are very harmful to the plant, seem to indicate the same conclusion. But it must be admitted that so far as the real significance and ultimate explanation of the phenomenon are concerned, no satisfactory solution is offered either by mere external appearances or by the purely biological features of the case.

A comparative study of the internal structure of normal and electrically curved roots has proved highly instructive in this connection. Fig. 4 shows a longitudinal section of the tip of a root of *Hyacinthus orientalis*, which had been acted upon for

half an hour by a current of ·8 milli-ampere density. The side of the root represented by the left-hand side of the figure was directed toward the positive pole. Here the cells are evidently in a state of partial collapse, the protoplasm is contracted, and the thin walls are more or less crushed. On the opposite side of the root there is every indication of a perfectly normal condition of the cells. Fig. 5 is from a longitudinal section of a root of *Hyacinthus orientalis*, after three hours exposure to a ·7 milli-ampere current. This section is taken from a part of root about 14^{mm} or 15^{mm} back of the tip, or at the point where elongation was most rapid at the time when the current was first turned on. It is perfectly evident that the cells on the concave side of this root, or the side toward the positive pole, were killed, while those on the opposite side kept on growing quite normally.

It should be mentioned in passing that when such curved roots are fixed in Flemming's fluid there is always a conspicuous white stripe down the concave side of the root, even after the other parts have turned quite brown or even black. This is an indication of the presence of dead cells in this region. The same thing is often shown in roots while the electric current is still acting upon them, by the fact that the concave side of the root becomes translucent from the escape of cell-sap into the intercellular spaces.

The harmful effects of the current are even more strikingly shown in cross-sections of the curved roots. Fig. 8 represents a transverse section at 10^{mm} from the tip of the root of *Hyacinthus orientalis*, after exposure to a ·7 milli-ampere current for one hour. Here the upper left-hand part of the section was directed toward the positive pole. Fig. 9 is from a section of such a root after two hours action of a similar current. In this case the upper right-hand side was toward the positive pole. Fig. 10 is an enlarged view of a part of the section shown in fig. 9, along the line between the more affected and the less affected parts. A comparison of these with fig. 6, taken from a section of a normal root, shows that there has been more or less shrinkage and collapse in all parts of the curved roots, but that the actually destructive action has been confined to the side toward the positive pole. This partial collapse of the entire structure is not evident in a root exposed to a ·1 milli-ampere current, while a very brief action of a strong current produces this effect in the entire root-tip, as shown in fig. 7, which is from a section of a root of *Hyacinthus orientalis*, treated for five minutes with a 10 milli-ampere current.

From these facts of the minute anatomy of electrically curved roots it seems to be self-evident that the curvature is the result of the paralysis and death of the protoplasm on one side of the structure, resulting in the complete arrest of development in that region, while the other parts go on growing in a more or

less perfectly normal way. As suggested in a former report,* this condition of the root is most satisfactorily accounted for by attributing the effects upon the protoplasm to the direct action of the positive electrons. That the effects are not of an ordinary chemical nature is evidenced by the fact that, so far as is known, the nature and rapidity of the response is conditioned solely upon the density of the current, regardless of the chemical composition of the electrolyte. This conclusion is based upon the results of large numbers of trials with a great variety of acids, bases, and salts, used always, of course, in extremely dilute solution, but giving, nevertheless, a wide variation in the chemical nature of the positive ions. But so long as the current density is kept constant the roots behave in precisely the same manner, regardless of the chemical composition of the electrolyte, provided always that the chemicals are so dilute as not to be directly and immediately harmful to the plants.

Upon the basis of the electron theory all the phenomena of electrotropism are readily and naturally explained. Whenever an electric current flows through an electrolyte, there is a stream of positive electrons flowing from the positive pole to the negative pole, while an equivalent stream of negative electrons flows toward the positive pole. Any object, such as the root of a seedling, dipping into the electrolyte parallel to the electrodes, will have that side toward the positive pole exposed to the stream of positive electrons, while the other side is equally exposed to the negative electrons. Consequently the cells on the side of the root toward the positive pole are sooner or later killed by the positive electrons, while the other side of the root continues to grow more or less vigorously, pushing the tip of the root around in the direction of the positive pole. When the growing end of the root has reached a horizontal position, or has become parallel to the streams of electrons, it is kept in that position, since any deviation would expose the more rapidly growing side to the positive electrons, with a consequent checking of the growth and a return to the horizontal position. The same explanation holds good in the case of roots which are placed originally in the horizontal position with their tips pointing toward the positive pole. That the delicate growing point is not at once killed when thus directed against the destructive stream of electrons is no doubt to be accounted for by the presence of the root-cap, which more or less effectually shields the meristematic tissue for a time at least.

Similarly we may explain the behavior of the seedlings used as electrodes. The positive one is injured only at the point of contact of the platinum wire, where the positive charge enters it. The part dipping into the water is receiving a stream of negative electrons, and consequently is uninjured. The negative seedling, on the other hand, is receiving a stream of posi-

* See this Journal, vol. xiv, p. 131, 1902.

tive electrons through its root, chiefly from the side toward the other seedling, hence it is curved and ultimately killed.

So far as can be made out from these studies up to the present time, the negative electrons are in no case harmful to plant protoplasm; and in several instances a marked acceleration in growth may reasonably be attributed to their influence. However, in the present state of knowledge, it would be imprudent to assert without qualification that negative electrons stimulate vegetable protoplasm.

A study is now being made of the effects of electric light and power-currents upon trees growing near to or in contact with the conductors. The facts thus far collected are in perfect accord with those outlined in this paper.

For the present, the point of principal interest lies in the fact that the phenomenon termed "galvanotropism" by Elfving has its ultimate cause in the effects of the electrons, or electricity *per se*, and apart from any streaming of ions or any ordinary chemical reaction. It is for this reason that the term "electrotropism" is deemed more appropriate than the term "galvanotropism" as used by Elfving.

Aside from their purely biological relations, the results of this investigation are of interest in their bearing upon the theory of ionization and upon the electron theory. For every new problem that is satisfactorily solved by a theory renders that theory more credible; and the problem of electrotropism is certainly of this nature, in its relation to the theories mentioned.

The results of these studies seem to indicate that whatever advantages may be derived from the use of electricity in practical horticulture are to be attributed rather to secondary chemical and thermal effects than to electrical energy as such, except perhaps in cases where the plants are negatively charged.

Harvard University, July, 1904.

EXPLANATION OF THE FIGURES, PLATES IX AND X.

Fig. 1. Cubette jar, with electrical connections, for subjecting roots of seedlings to the action of an electric current. (x $\frac{1}{6}$.)

Fig. 2. Young seedlings of *Zea mais*, after exposure for one hour to the action of a weak current. (x $\frac{1}{3}$.)

Fig. 3. Young seedlings of *Zea mais* which were exposed to the action of an electric current for one hour, then left in the water for an hour without current flowing. (x $\frac{1}{3}$.)

Fig. 4. Longitudinal section of a root-tip of *Hyacinthus orientalis*, which had been subjected to the action of an electric current for thirty minutes. (x 75.)

Fig. 5. Longitudinal section of a root of *H. orientalis*, showing the effect of three hours action of the electric current. (x 75.)

Fig. 6. Transverse section of a normal root of *H. orientalis*, 8^{mm} from the tip. (x 75.)

Fig. 7. Transverse section of a root of *H. orientalis*, 8^{mm} from the tip, after exposure for five minutes to a very strong current. (x 75.)

Fig. 8. Transverse section of a root of *H. orientalis*, 10^{mm} from the tip, showing effect of a moderate current acting for one hour. (x 75.)

Fig. 9. Transverse section of a root of *H. orientalis*, 12^{mm} from the tip, after exposure for two hours to a moderate current. (x 75.)

Fig. 10. A part of fig. 9 more highly magnified. (x 350.)

Fig. 2.

Fig. 3.

Fig. 1.

Fig. 4.

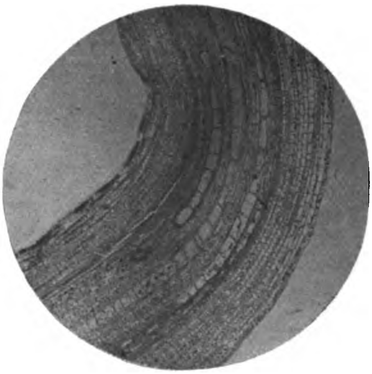


Fig. 5.

Fig. 6.

Fig. 7.

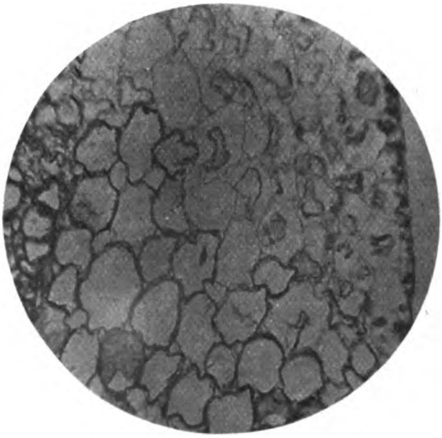


Fig. 10.

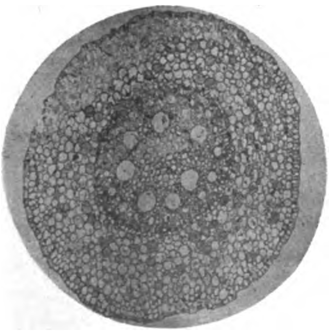


Fig. 8.

Fig. 9.

SCIENTIFIC INTELLIGENCE.

I. Geology and Mineralogy.

1. *United States Geological Survey.*—The following publications have recently been received:

Professional Papers No. 21.—Geology and Ore Deposits of the Bisbee Quadrangle, Arizona; by E. L. Ransome, 162 pp., 29 pls., 5 figs.—The lowest rocks of the Bisbee district are pre-Cambrian schists derived from arkose sediments and separated from the overlying Paleozoic beds by a profound unconformity. Cambrian quartzite, 4500 feet of limestone belonging to Cambrian, Devonian, and Carboniferous time, and 4500 feet of Cretaceous sediments constitute the strata represented. Faulting and folding accompanied by intrusions of granitic magmas and by mineralization occurred at the close of the Carboniferous. Later disturbance took place in post-Cretaceous time. The effect of intrusion of granite porphyry is inconspicuous. Faults in this region are numerous and the larger ones are located along a NW.-SE. tract about 2½ miles wide. Certain of the reversed faults are occupied by dikes intruded during the faulting. None of the workable ore deposits occur as lodes or fissure veins. With few exceptions the deposits, from which 400,000,000 pounds of copper have been taken, are irregular replacements of limestone.

No. 22.—Forest Conditions in the San Francisco Mountain Reserve, Arizona; by J. B. Leiberg, L. F. Rixon and A. Dodwell, with an introduction by F. G. Plummer, 91 pp., 7 pls.

No. 23—Forest Conditions in the Black Mesa Forest Reserve, Arizona; by E. G. Plummer from notes by L. F. Rixon and A. Dodwell, 60 pp., 7 pls.

No. 28.—Superior Analyses of Igneous Rocks from Roth's Tabellen 1869 to 1884, arranged according to the quantitative system of classification; by H. S. Washington, 51 pp. The chemical analyses of rocks published from 1884 to 1900 inclusive, are collected in Professional Paper No. 14. To this have now been added the more reliable and complete earlier analyses. The poor quality of early analytical work is made evident from Doctor Washington's selections. Analyses made previous to 1861 are discarded; of those made between 1861 and 1884 10·24 per cent are retained; and of those made between 1884 and 1900 64·70 per cent are worthy of permanent record. Of 5,303 analyses made between 1861 and 1900 inclusive, 2,112 or 39·83 per cent are classed as superior.

Bulletins. No. 224.—A Gazetteer of Texas; by Henry Gannett, 176 pp., 8 pls. As revised in the second edition the Gazetteer of Texas is a model for such work. Besides the list of place names, data are given regarding soil, climate, education, industries and other geographic elements.

No. 226.—Boundaries of the United States and of the several States and Territories; by HENRY GANNETT, 138 pp., 54 pls. The usefulness of this manual is shown by the fact that two previous editions have been exhausted. The history of all important changes of territory is given, together with a copy of the laws concerning them.

No. 229.—The Tin Deposits of the York Region, Alaska; by ARTHUR J. COLLIER, 57 pp., 7 pls., 5 figs. Tin ore probably of commercial value has been found in widely separated localities in the York region. The ore occurs in alluvial deposits occasionally traced to small veinlets in slate, and in well-defined veins of greisen associated with siliceous intrusions. Mr. Collier gives a valuable general discussion of the occurrence and method of working tin, and adds a bibliography of the subject.

No. 230.—A Gazetteer of Delaware; by HENRY GANNETT, 15 pp.

No. 231.—A Gazetteer of Maryland; by HENRY GANNETT, 84 pp.

FOLIOS. No. 101.—San Louis Folio, California, by H. W. FAIRBANKS. The Coast Ranges of California are exceedingly complex in their geologic structure and students will welcome this description of a typical area. The sedimentary rocks represented belong to Jura-trias, Cretaceous, Neocene and Pleistocene formations, and the igneous rocks, both extrusive and intrusive, date from these same periods except the Pleistocene, and there is in addition a pre-Triassic granite. The igneous varieties represented are granite, diabase, basalt, augite-teschenite, olivine-diabase, quartz-basalt, rhyolite, tuff, pyroxene-andesite, peridotite, pyroxenite, norite, gabbro, andesite-granophyre and dacite-granophyre. The Jura-trias rocks contain molluscan remains not found elsewhere on the Pacific coast. Lens-shaped bodies of jasper occur with the sandstone, and there is an abrupt change from the rock containing siliceous tests of radiolaria to the shallow water formation showing no radiolaria. Abrupt alterations of currents, or depth, or shore line, must have taken place. Lenticles of glaucophane schist from 1 foot to 100 feet in thickness are irregularly formed and ascribed to contact metamorphism. The volcanic eruptions connected with the Monterey shale (Neocene) occurred beneath the sea and consist largely of ash and pumice. The pumice has become so impregnated with pyrite as to form a very resistant rock in which shore terraces are cut. In its topographic development this region presents an interesting study of planation, stream adjustment and of development of a coast line during several periods of elevation and depression. The San Louis valley has been developed by two sets of tributary streams, while the master stream crosses the valley at right angles and enters a canyon. The Salinas is an excellent example of a superimposed stream. It flows in a granite-walled canyon parallel with and a short distance from a wide valley cut in soft rock. Numerous faults are described by

Professor Fairbanks, one with a throw of 2000 feet, yet no fault lines are shown on the map, because "not clearly defined in the field." They are shown, however, in the structure sections and it would be of advantage to students if a less conservative attitude had been adopted in constructing the areal map.

No. 107.—Newcastle Folio, Wyoming–South Dakota; by N. H. Darton.

No. 108.—Edgement Folio, South Dakota–Nebraska; by N. H. Darton and W. S. Tangier Smith.

The three folios (Nos. 85, 107, 109) which describe the geology of the edge of the Black Hills uplift are interesting, because of their local features, and because they furnish such excellent illustrations of simple monoclines, erosion forms and stream systems. They are destined to be much used in teaching.

No. 109.—Cottonwood Falls Folio, Kansas; by C. S. Prosser and J. W. Beede. This quadrangle is part of the Great Plains province and is underlaid entirely by Carboniferous rock, mostly limestone. The topographic features are due to erosion of nearly horizontal strata.

2. *Geological Survey of Canada.* Summary Report for 1903. 212 pp., 7 maps.—For the year 1903 the staff of the Canadian Survey numbered 57, and Dr. Bell had at his disposal an appropriation of $133,000. Economic work has received chief attention, and parties have been at work investigating mineral resources in Yukon Territory, British Columbia, Ontario, Quebec, New Brunswick and Nova Scotia. Mr. R. W. Brock describes the Physiography of the Lardeau District, one of the most rugged and picturesque portions of the Selkirks. Dr. R. A. Daly continued his work along the international boundary. He found the conditions exceptionally favorable for structural studies. Three master thrust faults occur. One of them lies in the plane of bedding and the blocks have been rotated and overturned. Additional evidence is found in support of the hypothesis of "overhead stoping" as a mode of igneous intrusion. The work of the survey is retarded by the lack of adequate topographic maps.

3. *Examination of the Coral-Rock Cores from the Borings at Funafuti.*—The general report upon the borings made in the coral rock of the atoll of Funafuti has already been noticed in a recent number (vol. xvii, p. 478, June, 1904); some of the results, however, which have been reached by Prof. J. W. Judd and Dr. C. Gilbert Cullis, in the minute chemical and microscopical examination of the cores of coral rock obtained deserve more detailed presentation. It will be remembered that the main boring was carried to a depth of 1114½ feet, while two other minor borings were also made at an earlier date. Samples from the former boring yielded 133 analyses, and those from the latter 72 analyses.

The chief result of this careful chemical work is to show that in the first 50 feet of descent there is a gradual rise in the per-

centage of magnesium carbonate up to 16 per cent; this maximum occurring at depths of 15 and 25 feet, with a falling off between these depths to 12 per cent. From a depth of 25 feet there is a gradual decline in the proportion of magnesium carbonate till 50 feet is reached, where only the normal amount of 1 to 5 per cent is present. This latter relation continues from 50 to 637 feet. From here down, however, the percentage rises rapidly, so that at a depth of 658 feet the proportion of magnesium to calcium carbonate reaches the limit of 40 to 60. This high percentage of 40 per cent is maintained to the bottom* (1114½ feet) with small variation (except for two interruptions to be mentioned), the maximum of 43 per cent being reached at 950 feet. Exceptional conditions were noted twice: between 819 and 875 feet, the proportion of $MgCO_3$ varies widely with a minimum of 4·8 per cent at 826 and a second of 20·6 per cent at 866, and a maximum of 28·5 per cent at 855 feet. Again, between 1050 and 1097 feet there is a falling off, with a minimum of 26·63 per cent at 1061 feet and 30·7 per cent at 1080 feet, and a maximum of 39·4 per cent at 1070. These wide variations remain unexplained.

In regard to other constituents in the rock, it may be briefly stated that the amount of organic matter in the samples examined was found to be extremely small; at depths below 100 feet quite inappreciable; insoluble inorganic matter was also shown to be almost completely absent, as is true in general of coral reef rocks not formed near volcanic masses. The amount of phosphates present was in all cases minute and often quite inappreciable.

The chief interest in regard to the facts stated centers in their bearing upon the important problem of the dolomitization of limestone rocks. This subject is discussed with much thoroughness by Professor Judd. Attention is called to the established fact that the amount of magnesium carbonate present in living corals is small. The greater solubility of the calcium carbonate, however, tends to increase the relative amount. The rapidity of the leaching-out process depends upon the special conditions of temperature and pressure, and further varies widely with different organisms, being greater with those (as the algæ) in which organic matter is present to considerable amount.

This process of leaching-out seems to offer an adequate explanation of the increase in the magnesium carbonate up to 16 per cent, which as stated was observed in the upper part of the cores. The much greater rise in the proportion from a depth of 637 feet to the bottom, reaching a maximum of 43 p. c. at 950 feet, requires another explanation. Here, moreover, as shown by the examination by Dr. Cullis mentioned below, the mineralization, slight above, is prominent, the cores are fairly solid and distinct crystals of dolomite are formed to a greater or less extent throughout the mass.

The author's views can best be presented by quoting his words.

* Normal dolomite calls for 45·65 per cent.

Speaking of the mass resulting from the leaching-out of the calcium carbonate with its enrichment in magnesium, the author adds: "Now this mass in a coral reef is everywhere permeated and acted upon by sea-water containing a very notable proportion of magnesium, principally in the condition of chlorides and sulphates. May not these materials enriched by the magnesium carbonate exercise an attractive action on the magnesium salts of the ocean waters, giving rise to double decomposition and the gradual replacement of a part of the calcium in the carbonates by magnesium." . . . "It by no means follows that, because the dolomite crystals are found only at considerable depth, the action to which the formation of the crystals was due took place only at this depth. The action may possibly have taken place at or near the surface and the rock have subsided after its alteration. At the same time it may be noted that all the rocks now at short distances from the surface in Funafuti show no dolomite crystals and contain only such an amount of magnesium carbonate as may be accounted for by the leaching-out process."

The author adds in closing: "From what has been said, it will be apparent that while the investigations that have been carried on upon materials obtained in the vertical borings of Funafuti and also in specimens obtained from upraised reefs in the Indian and Pacific oceans, show that the dolomitization of coral-reef rock, first demonstrated by the researches of Dana and Silliman, really takes place sporadically over very wide areas, the exact conditions under which the operations occur still call for careful investigation both by observation and experiment."

The mineralogical changes in the cores from the Funafuti borings have been carefully investigated by Dr. Cullis and the results are described with many excellent illustrations in Section XIV of the Report. The discrimination between the three constituents of the coral rock, calcite, aragonite and dolomite, was aided by the use of methods of staining, one of which (after Meigen) served to separate the aragonite from calcite and dolomite, the other (Lemberg) the dolomite from the other species. Speaking generally, it was found that aragonite occurs in the upper cores only and dolomite only in the lower ones (below 637 feet), while calcite, which is the sole constituent of the middle cores, occurs with aragonite above and with dolomite below; aragonite and dolomite were in no case found associated.

The microscopic examination of the cores down to a depth of 637 feet shows the original rock unchanged in the first few feet only; below this point a greater or less degree of alteration has gone on. The changes noted in the first 637 feet include the deposition of secondary calcite and aragonite from solution, the former generally and the latter always in continuity with the same mineral in the original organisms; also the crystallization of the finely divided calcareous detritus and finally the gradual disappearance of the aragonite. As already stated, no individualized dolomite is found in the upper cores even where partial

dolomitization has gone on and the percentage of magnesium carbonate has increased to 16 per cent. Another point of interest is that near the surface masses of dense solid coral rock are common, farther down these are rare and between 220 and 637 feet they do not exist, the material resembling unconsolidated coral reef sand. This difference is explained by the effect of the more complete solution and removal of the original aragonite. When the original rock consisted chiefly of calcite this has been less affected by solvent action and the rock is sufficiently coherent to yield more or less solid cores; when aragonite was more prominent its removal has left the rock in a fragmental and incoherent condition.

A marked change begins with the core at 638 feet; here a large percentage of magnesium carbonate is found, making as before stated a maximum of 43 per cent at 950 feet, and with the exceptions mentioned on p. 240, this condition is maintained to the bottom mineralogically. This means that the cores consist of dolomite, in many cases in the form of distinct rhombohedral crystals, while recognizable calcite has largely or completely disappeared. A feature of the lower cores (from 815 feet down) is the presence of fibrous deposits gradually increasing in relative amount; at first this consists entirely of calcite, at greater depths of alternate layers of calcite and dolomite; in one case (1090 feet) five such layers were observed. Many interesting variations are noted in the microscopic sections in the appearance of the dolomite and calcite and their relations to each other and to the original organisms. These are clearly described and in addition are distinctly presented to the eye in the admirable series of figures, all of which deserve to be carefully studied. Enough has been said, however, to indicate the general conclusions arrived at and to show that this unique investigation serves to throw much light on some of the most difficult problems in connection with the history of the coral reef.

4. *Brief notices of some recently described Minerals.*—Bakerite is a new borosilicate of calcium described by W. B. Giles from the mines of the Borax Consolidated Company in the Mohave desert, 16 miles northeast of Daggett, San Bernardino county, California. It occurs in white, amorphous masses forming veins and nodules of considerable size. In appearance it resembles unglazed porcelain or fine-grained marble; occasionally it has a faint greenish tinge. Hardness = 4·5, specific gravity 2·73. An analysis yielded the following results:

B_2O_3 27·74 SiO_2 28·45 CaO 34·88 H_2O 8·30 Al_2O_3,Fe_2O_3 0·63 = 100.

From this the formula is calculated $6SiO_2 . 5B_2O_3 . 8CaO . 6H_2O$. The mineral is named after Mr. R. C. Baker, a director of the company. It is noted that howlite also occurs in large quantities in the same mines.—*Min. Mag.*, xiii, 353.

Erikite is a new species from the nephelite-syenite of Julianehaab, Greenland, described by O. B. Böggild. It occurs in orthorhombic crystals, sometimes highly modified, of a yellowish

brown to dark grayish brown color. Specific gravity 3·493, hardness 5·5 to 6. The crystals are opaque and under the microscope are seen to have a pseudomorph-like structure consisting of a complex yellow substance of strong double refraction and a colorless one feebly birefringent. An analysis by Chr. Christensen yielded:

SiO_2	P_2O_5	$(Ce, La, Di)_2O_3$	ThO_2	Al_2O_3	CaO	Na_2O	H_2O
15·12	17·78	40·51	3·26	9·28	1·81	5·63	6·28 = 99·67

The formula of the mineral is doubtful because of the alteration it has undergone. Erikite is named after Erik the Red, who discovered Greenland in 986. The same author gives a further description of the rare species *schizolite* (see this Journal, x, 325, 1900), first described by Winther from the same region in Greenland. It is shown to be triclinic in crystallization and nearly similar in form to pectolite and wollastonite; it is also related to rhodonite and babingtonite.—*Medd. om Grönland,* xxvi, 1903.

Cryolithionite is a new fluoride of aluminium, sodium and lithium described by N.-V. Ussing from the cryolite locality at Ivigtut, Greenland. It occurs in large dodecahedral crystals which are colorless and show distinct dodecahedral cleavage. The hardness is 2·5 to 3 and the specific gravity 2·777. An analysis of purified material gave:

F 60·79 Al 14·46 Na 18·83 Li 5·35 ign 0·36 = 99·79

This leads to the formula $Li_3Na_3Al_2F_{12}$, which corresponds to a cryolite with half the sodium replaced by lithium.—*Bull. Acad. Sci. Lettr. Danemark,* No. 1, 1904.

Thorianite is a new radio-active species from the gem washings at Balangoda, Ceylon, named by W. Dunstan; it has also been observed in pegmatite at Gampola, Ceylon. It occurs in black cubical crystals of specific gravity 9·32. An analysis by G. S. Blake gave the following results:

ThO_2	$(Ce, La, Di)_2O_3$	UO_2	ZrO_2	Fe_2O_3	PbO	SiO_2
76·22	8·04	12·33	*tr*	0·35	2·87	0·12 = 99·93

The same mineral has been examined by W. Ramsay as to its radio-activity and chemical composition, with results in the latter direction that do not agree with the analysis above quoted.—*Nature,* lxix, 510, 533, 559.

5. *New York State Museum.* 22d Report of State Geologist, 1902. 186 pp., 29 pls.—In addition to the economic work conducted under Dr. Merrill's direction, investigations on the crystalline and Pleistocene rocks were continued.

New occurrences of anorthosite on the Langlake sheet are reported and studied by Prof. Cushing. Prof. Woodworth continued his detailed study of the Hudson-Champlain depression and mapped new shore lines marked by bars, embankments and terraces. Pages 17–41 of the present report is a paper by Prof. H. L. Fairchild on Glacial Waters from Oneida to Little Falls. The history of the Mohawk Valley drainage is divided into three stages: 1. Pre-Iroquois waters—lacustine, and fluviatile, held in

the valley during the ice retreat; 2. Iromohawk river—draining glacial lake Iroquois and cutting the rock channel at little falls; 3. The Mohawk River.

6. *Observations of a Naturalist in the Pacific;* by H. B. GUPPY. Vol. I, Vanua Levu, Fiji, xix, 392 pp., 7 plates, 2 maps, 20 figures. London, 1903 (Macmillan & Co.).—This handsome volume describes in great detail the geology and petrography of Vanua Levu. The author concludes that "Vanua Levu is a composite island built up during a long period of emergence, that began probably in the late Tertiary period, by the union of a number of islands of volcanic formation." The platform on which the island rests is supposed to be built up of submarine basaltic flows. The rocks are chiefly basalts and andesites, with a few dacites, trachytes, quartz-porphyries, gabbros and diorites. The author adopts a peculiar classification of his own for these: Classes being based on the ferromagnesian mineral present, the Sub-classes on the presence or absence of groundmass, Orders on the arrangement of the groundmass feldspars, Sub-orders on the ferromagnesian mineral of the groundmass, Sections on the presence or absence of feldspar phenocrysts, Genera on the vitreous or opaque character of these, and Species on their length. There is no discussion of the reasons for the adoption of this classification, criticism of which is uncalled for here. Although the rocks are described petrographically in great detail, not a single chemical analysis of them is given. A chapter is devoted to the magnetic characters of the volcanic rocks, many of which are stated to show marked polarity. Vol. II will deal with the dispersal and distribution of Pacific plants. H. S. WASHINGTON.

II. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Elements of Algebra for Beginners;* by GEORGE W. HULL, 159 pp. American Book Company.—This little book has been prepared for young pupils as a substitute for some of the later work in arithmetic. It does not afford a basis of instruction adequate for preparation for college examinations, nor does it aim to do so. For teaching the technique of algebra, the book is admirably adapted, though in some cases, notably in evasion of negative numbers, the aim for simplicity runs counter to sound science. The collection of examples includes many simple ones carefully graded. H. E. H.

2. *Elementary Algebra;* by J. H. TANNER. American Book Company.—This book is adequate for the preparation of students for the examinations in Elementary Algebra for any college or scientific school. The development of the numbers used in algebra is careful, and the most striking feature of the book. To a class of somewhat mature students, the book would undoubtedly be of value. H. E. H.

A "Complete Mineral Catalog" in handsomely printed form has recently been issued by the Foote Mineral Co. 216 pp., price 25c., in flexible cloth, 50c.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXVIII.—*A New Devonian Formation in Colorado*; by WHITMAN CROSS.

THE existence of Devonian formations in the San Juan region of Colorado was first established through the discovery of invertebrate fossils by F. M. Endlich of the Hayden Survey, during the summer of 1874.* The Devonian character of the fauna discovered by Endlich was announced by F. B. Meek,† later questioned by C. A. White‡ and R. P. Whitfield,§ reaffirmed by C. Schuchert,** and finally established by G. H. Girty†† upon the basis of extensive collections from many localities obtained during the survey of the San Juan country under the direction of the writer. The limestone formation, from which Endlich collected a few fossils and which has yielded the extensive fauna studied by Girty, was described by A. C. Spencer,‡‡ at the time the writer's assistant in the Colorado work, as the *Ouray Limestone.* It has been found, since the cited publications by Spencer and Girty, that the upper part of the lithologic unit, the Ouray limestone, contains a Mississippian Carboniferous fauna. This has now been described by Girty,§§ in his review of the known Carboniferous

* Ann. Rep. U. S. Geol. and Geog. Survey, etc., for 1874, pp. 211-214.
† Bull. U. S. Geol. and Geog. Survey, etc., 2d Ser., No. 1, 1875, p. 46.
‡ Bull. U. S. Geol. and Geog. Survey, Terr., 2d Ser., No. 1., 1875, p. 47.
§ U. S. Geol. Survey, Monog. XII, 1886, p. 56.
** Bull. U. S. Geol. Survey, No. 87, p. 166.
†† Devonian fossils from Colorado. The Fauna of the Ouray Limestone. U. S. Geol. Survey, 20th Ann. Rep., Pt. II, 1900, pp. 25-81.
‡‡ "Devonian Strata in Colorado," this Journal (4), ix, 1900, p. 125.
§§ "The Carboniferous Formations and Faunas of Colorado;" Profession. Paper No. 16, U. S. Geol. Survey, 1903.

invertebrates of Colorado. The Ouray limestone has been studied in several quadrangles of the San Juan region, the original locality at which its Devonian fauna was first discovered by Endlich has been revisited, and its position as a well determined unit in the Paleozoic section of Colorado must be considered as established. The present paper refers to the immediately underlying formation, in which Endlich found fish remains, and which is now for the first time given a distinctive name.

The locality at which Endlich first observed the Devonian strata lies upon the southern slope of the Needle Mountains, about 10 miles east of the Animas canyon at Rockwood, and on the western rim of the Vallecito canyon. The beds are very near the base of the Paleozoic section which dips southerly under the influence of the post-Laramie domal uplift about the Needle Mountains center. Erosion has removed the sediments over a large area, in places exposing the coarse-grained granite upon which they rest and here and there leaving tongues or isolated patches of the lower formations.

The Devonian invertebrates were found by Endlich at a triangulation station, obscurely referred to in his report as "Station 48," which is easily identifiable from the topographic report of 1874 as the point of elevation 12,305 feet, according to the Hayden map, directly overlooking the Vallecito canyon and a little south of the boundary of the Needle Mountains quadrangle. A stone monument still stands at the point, upon a remnant of Ouray limestone very rich in fossils and near the base of the formation. A branch of the Vallecito, heading west of the point, cuts it off from the main sloping mesa of sedimentary rocks, which begins a half mile to the southwest. In the absence of sufficient geographic terms for descriptive purposes, the writer proposes the name "Devon Point" for this knoll capped by Ouray limestone, the "Station 48" of the Hayden survey, which must become a classic spot in the discussion of the Colorado Devonian. The name Endlich Mesa has already been given, upon the Needle Mountains topographic map, to the gently dipping surface of granite and thin overlying Paleozoic beds which lie between the Vallecito and the Florida rivers, and is terminated by the headwaters of the latter stream. Devon Point lies on the eastern edge of Endlich Mesa.

Below the triangulation monument of Devon Point there are but about 25 feet of the Ouray limestone. Intervening between the limestone and the granite are two distinct formations referred to by Endlich* in the following terms, which (as to the upper

* Loc. cit. pp. 211, 212.

one) specifically apply to the exposures southwest of Devon Point about one-half mile, where the sediments reappear beyond the stream above mentioned, which has cut through them into the granite. They apply as well, however, to the strata at Devon Point.

"Resting immediately upon this granite, which showed a very marked stratification, conformable with that of the superincumbent sedimentary beds, a white to red and brown quartzite was found. At some points the contact of the latter with the granite was so intimate that specimens could be obtained, showing both the granular quartzite and the coarse-grained granite on the same piece. No definite relation of the colors exhibited by the quartzite could be established, save the general rule that the nearer it was to the underlying metamorphic rock, the more intensely it was colored." * * "Above the quartzite is a thin stratum of yellow siliceous shales, containing narrow interstrata of softer shales. In these the well-known and characteristic pseudomorphs after salt were found. During the formation of the Devonian beach that now remains quartzite and quartzitic shales, portions of the water, that even at so early a geological period contained sodium chloride, were separated from the main body. Upon evaporation the mineral constituents of the water crystallized. Subsequent inundations of the places that had scarcely been laid dry, brought with them sand and silt, covering the newly formed crystals. By the gradual percolation of water through the cover the salt was dissolved, and a quantity of the material composing the cover found its way into the cavities thus produced. It will be noticed, therefore, that whenever these pseudomorphs of sand after salt are found *in positu*, the crystals will be observed on the *lower* side of the stratum containing them. Occurrences of this kind are not infrequent in younger formations both of this country and Europe. Besides these pseudomorphs, scales and fragments of bones are found, belonging to some fish of considerable size. Too little material could be collected to admit of any identification, even only generically. Small scutellae also occur, probably belonging to the same animal. This stratum, as well as the quartzite underlying it, can be traced on the southern side of the granite strip." *

In the summer of 1901 the southern portion of the Needle

* Endlich conceived the granite of this region to be an extreme product of the metamorphism of early Paleozoic sediments, and this view seems to have influenced his statement that at Devon Point the granite "showed a very marked stratification, conformable with that of the superincumbent sedimentary beds." In fact, the granite is unusually coarse-grained, massive, and homogeneous in composition, exhibiting nothing to warrant the repeated references to its origin from sediments.

Mountains quadrangle was mapped geologically by the writer, assisted by Ernest Howe and J. Morgan Clements. Devon Point and the exposures to the southwest were visited, but as the remark of Endlich concerning the fish remains had escaped attention, they were overlooked in the effort to secure fossils from the Ouray limestone. In 1903, however, a special trip was made by the writer and Mr. Albert Johannsen to Devon Point and the adjacent exposures in special search for the fish remains.

The relation of the beds at this locality is shown in the accompanying detailed section.

Section of Paleozoic Formations, Devon Point, Colorado.

TOP.		FEET.
	Ouray limestone remnant, estimated	25
	Elbert formation.	
12.	Red shale or clay. Strong red color, uniform composition; when dry makes soft, crumbling flakes at exposures	5
11.	Sandstone or quartzite. A layer of variable grain, fine or coarse, not persistent, gray, full of fragments of fish scales in some places; free from them in others	± 1
10.	Calcareous shales and thin limestone, buff or gray in color, breaking up readily into slabs or flakes. Salt casts are common in this division. A thin, discontinuous red purplish, sandy layer full of scale fragments occurs locally	25
9.	Thin layers of quartzite, limestone, and red calcareous shale, alternating. Limestone is arenaceous, dull gray, few layers reaching 6 inches in thickness	8
8.	Quartzite, fine-grained, gray, hard, in layers 2 or 3 inches thick	2-$\frac{1}{2}$
7.	Red, calcareous shale	1-$\frac{1}{3}$
6.	Limestone, yellow, earthy	-$\frac{3}{4}$
5.	Calcareous and sandy shales, variegated, yellow, buff, lilac	1-$\frac{1}{4}$
4.	Quartzite, fine-grained, yellow-brown	1-
3.	Sandy shale, a harder layer in middle. Red, greenish, or mottled	5-
2.	Sandy limestone, shaly in part, rich in fish scales and plates	± 1-
1.	Red shale, calcareous, and sandy, with specks of bone or shell	2-
		54

TOP.		FEET.
	Ignacio formation.	
5.	Quartzite conglomerate with small pebbles, gray or pink, hard and causing a distinct ledge (may belong to Elbert)	3–½
4.	Quartzose sandstone and sandy shale, dark dull red, in layers 6 inches or less in thickness	5
3.	Quartzite, fine-grained, hard, gray, in beds 1 to 5 feet in thickness with thin shale partings. Cross-bedding common	24
2.	Sandstone and quartzite, fine and uneven grain in beds 2 or 3 feet thick, with red, sandy shale layers between	17
1.	Crumbling shaly sandstone, dark, dull red in color, mainly of quartz with some red feldspar grains. A coating of limonite on particles causes color	2–½
		52–

Base of section is coarse biotite-granite.

The quartzite formation, measuring 52 feet in thickness at Devon Point, is called the Ignacio quartzite in the Silverton folio (now in press) and it is believed to be of Upper Cambrian age, since the only fossil thus far found in it is a small shell which, according to Mr. Charles D. Walcott, is apparently an *Obolus*, closely related to *O. loperi*, known elsewhere in Colorado. The strata between the quartzites and the Ouray limestone, carrying fish remains at the base and also near the top, seem unquestionably to form a lithologic stratigraphic and faunal unit, and for these strata the name *Elbert formation* is here proposed. The name is derived from Elbert creek, a western tributary of the Animas, entering it just above Rockwood, which flows for several miles on a broad bench between the Animas canyon and the high scarp formed by the Hermosa Upper Carboniferous formation. On this bench the Ignacio, Elbert and Ouray formations are particularly well exhibited. The first name is from the Ignacio lakes, lying on this bench and drained by Elbert creek.

The Elbert formation has been observed below the Ouray limestone in several quadrangles of the San Juan region and many exposures have been studied. While the reader is referred for details to the Needle Mountains, Durango, Engineer Mountain, and Silverton folios, now in press, or soon to be completed, some statements of its characteristics may be made.

Its general lithologic character is fairly well illustrated by the section at Devon Point, although many of them have been noted. The most persistent feature is the crumbling calcareous

shale division, with its casts of salt crystals, by which it may quickly be recognized in nearly all localities. Especially where the formation is found capping a bench or isolated knoll, as at Overlook Point and several other places on the granite surface north from Endlich Mesa, the thin limestone slabs covered with these casts are often very abundant. As was noted by Endlich, the casts were found on the under-surface of layers and testify to peculiar local conditions. While commonly on earthy limestone, the casts have been noted on coarse quartzose sandstone. The most important variation in the lithologic character of the Elbert formation is in the appearance of dense, earthy limestone of conchoidal fracture, in several beds in its upper portion. This development is most notable on the west flank of the Needle Mountains, and also at Bluebird Park, in the northwestern section of the Needle Mountains quadrangle.

The only fossils as yet obtained from the Elbert formation are fish remains, and the most productive locality discovered is that of Devon Point, already described. The remains were found at the base, and also very near the top of the section referred to the Elbert, showing the formation to be a well defined unit as to its fauna. Fish remains have also been discovered at two other localities, to be briefly mentioned.

At about one mile south of Rockwood, and close to the railroad track, a block of pale reddish quartzite was found at the base of the talus slope, upon which were rather indistinct remains of three individual fishes. The ledge of quartzite just above this talus heap belongs to the Ignacio Cambrian quartzite, but the sloping bench between that ledge and the cliff of Ouray limestone some yards farther back is occupied by the Elbert formation. Repeated search has failed to reveal the stratum from which the fish-bearing slab came, and no other remains were obtained. It is almost certain, however, that the slab in question came from a thin bed in the lower part of the Elbert section.

Another, and somewhat different, occurrence of fish remains was found on Little Cascade creek, about one-half mile south of Columbine lake and seven and one-half miles north of Rockwood. At this point the shales containing salt casts are succeeded by several massive limestones alternating with shaly strata. Several thin layers rich in finely comminuted fish scales or plates occur beneath the limestones, and in one of the limestones, resting with irregular contact upon such a layer, a few large plates were found.

All the fish remains above mentioned have been examined by Dr. C. R. Eastman, who, in the accompanying paper, describes the fauna represented by them and discusses their interest from the paleontological standpoint. From the strati-

graphic point of view, the discovery of this distinct ichthyic fauna leads to certain correlations and gives much desired information concerning the lower Paleozoic section of western Colorado.

The most evident correlation of the Elbert formation is with the so-called "Parting Quartzite" of central Colorado, in which Spurr found fish remains determined by Eastman as of Upper Devonian character, and related to certain forms from the Elbert formation.

The name "Parting Quartzite" was used by Emmons in the Leadville monograph* for a quartzite formation 70 feet or less in thickness, occurring below the "Blue Limestone" in which Lower Carboniferous fossils had been found, and the "White Limestone," supposed to be of Silurian age. The "Parting Quartzite" was also provisionally assigned to the Silurian.

At Aspen, on the northeastern flank of the Elk mountains, Spurr † found the beds corresponding in stratigraphic position to the Parting Quartzite of Leadville, to consist of alternating dolomite, dolomitic shale, and quartzite, the last on the whole subordinate, but the old name for the formation was retained. From certain shaly beds at Aspen, Spurr and Tower obtained the fish remains referred to by Dr. Eastman in the accompanying paper. Upon the provisional determinations of this material by Walcott and Girty, the Devonian age of the "Parting Quartzite" was advocated by Spurr. He also pointed out the resemblance of the fish-bearing formation of Aspen to the beds observed by Walcott ‡ in the lower Kanab valley of Arizona, briefly stated to contain "placoganoid fishes of a Devonian type."

The stratigraphic equivalence of the Elbert formation of the San Juan region with the "Parting Quartzite" is further supported by the correlation of the Ouray and Leadville (Blue) limestones, rendered necessary by the studies of Girty, who shows that both possess an upper Devonian invertebrate fauna in their lower portions and a Mississippian fauna in their uppermost strata. The Carboniferous forms only were found at Leadville, and the Devonian fauna was the first obtained from the Ouray limestone.

The correlation of the Elbert formation and the "Parting Quartzite" with the strata of the Kanab valley, already suggested by Spurr, is of special interest in view of the relations of the Elbert fishes and the suggestions made by Eastman regarding the geographic connections of that fauna. Unfortu-

* Mon. U. S. Geol. Survey, vol. XII, p. 61.

† "Geology of the Aspen Mining District, Colorado," U. S. Geol. Survey, Mon. XXXI, 1898, pp. 13-22.

‡ This Journal (3), vol. xx, 1880, p. 224.

nately the fossils obtained by Walcott in the Kanab section are not at present available for comparison with the Colorado forms. As Spencer pointed out in discussing the relations of the Ouray limestone,* "it is very probable that the lower part of the Red Wall limestone [Kanab section] is equivalent in age, as well as in position, to the Devonian limestone of Colorado."

While certain correlations for both the Elbert and Ouray formations seem definitely indicated by present knowledge, meagre as it is in some directions, there is a marked contrast between the lower Paleozoic section of western Colorado and that of the Front range, especially as exhibited near Canyon City.

A marked difference also exists between the Kanab section and that of central Nevada, and other localities of the Great Basin. The faunal problem involved is pointed out by Dr. Eastman, and it is clear that the conditions controlling the character of the sedimentary beds form also a most inviting subject for investigation.

* This Journal (4), vol. ix, 1900, p. 133.

Art. XXIX.—*On Upper Devonian Fish Remains from Colorado;** by C. R. Eastman.

Through the courtesy of Drs. Whitman Cross and T. W. Stanton, of the United States Geological Survey, a number of Paleozoic fish remains from Colorado have recently been placed in the hands of the writer for investigation. The greater number of these were collected by Dr. Cross in the San Juan region, while engaged on the survey of the Durango, Engineer Mountain, and Needle Mountains quadrangles. A few detached plates and scales from Aspen, collected some years ago by J. E. Spurr, complete the collection. The character of the remains is indicative of an Upper Devonian horizon for all the localities, and in the case of at least two of them, an Upper Devonian invertebrate fauna has been found in beds overlying the fish-bearing strata. For an interesting account of the stratigraphy of the region, the reader is referred to the preceding paper by Dr. Cross, wherein the name of Elbert formation is proposed for the fish-bearing beds. In the present article it will be sufficient to point out the general nature of the vertebrate fauna, and to inquire into its relations with other Devonian assemblages. The several localities may be considered in the following order.

Durango Quadrangle.

The specimens from the Elbert formation of Rockwood being of exceptional interest, the details of their occurrence may be noted rather fully. They are all from a single slab of quartzite found in the talus at the base of a cliff about one mile south of Rockwood. It is stated by Dr. Cross in memoranda accompanying these specimens that their probable source, as indicated by lithological evidence, is "at least 100 feet above the basal conglomerate, which here rests upon granite. Above the quartzite ledge, with a small covered interval, comes the Ouray limestone, containing a Devonian invertebrate fauna. The variable quartzite series below the limestone in the Animas Valley never exceed 300 feet in thickness, and have yielded no other forms, though carefully searched for a number of miles along the outcrop. . . . The occurrence of fish remains in the Silurian at Canyon City, as described by Walcott, suggests that these fish remains from near Rockwood belong to Silurian beds intermediate between the Cambrian and the Devonian. Very careful search did not suffice to detect the layer from which the slab in question came." In a

* Published by permission of the Director of the United States Geological Survey.

later communication he remarks that "the greater part of the quartzite above the talus heap is supposed to belong to the Cambrian member of the series, and the Elbert formation is known on the little bench just at the head of the talus pile. For some time past I have regarded it as almost certain that the slab came from the Elbert formation."

The recognizable specimens on this slab are three in number, and all belong to a large species of Bothriolepis which cannot be identified with any previously described. Exceed-

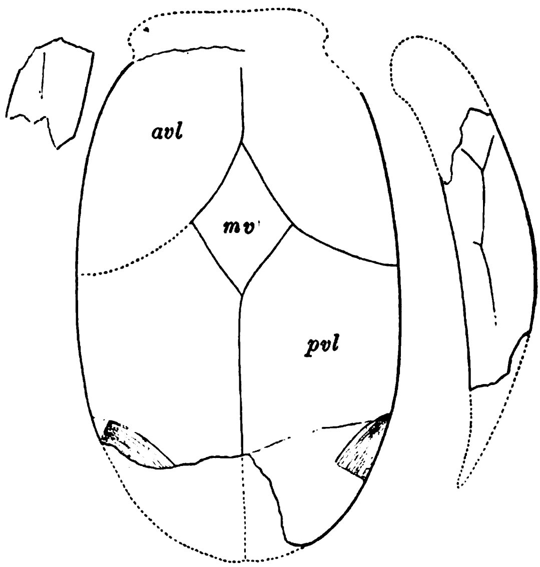


FIG. 1.—*Bothriolepis coloradensis*, sp. nov. × ½.

ing the average of *B. canadensis* in size, it is slightly inferior to *B. major;* but from both of these the new species is distinguished by its different style of superficial ornamentation, general proportions of the body and appendages, and by peculiarities in the outline and structure of the ventral plates. It is difficult to frame a satisfactory diagnosis of the new form, all three individuals presenting only the ventral aspect, and none of them exhibiting the head, though the pectoral members are attached. At the same time it is possible to form a fairly accurate concept of the relations between this and other species, and for sake of comparison with the well known *B. major*, figures are given showing the topography of the ventral surface in each (figs. 1, 2). In *B. canadensis* the rhom-

boidal median ventral is relatively smaller, and the surface ornamentation of all the plates is finer and of different pattern. The appendages, too, are longer, and more tapering distally. *B. major* has the median ventral larger and more exposed than in any known species, its outline being sometimes polygonal or slightly rounded (fig. 3). The remaining species of Both-

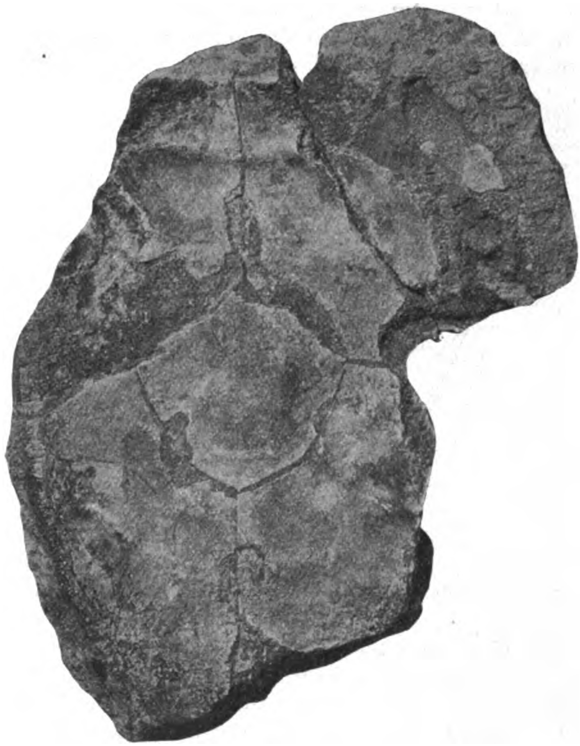


Fig. 2.—*Bothriolepis major* (Ag.). $\times \frac{5}{8}$.

riolepis are excluded from comparison with the new form, which may be known as *B. coloradensis*, by reason of their smaller size, or nature of their superficial ornamentation.

The ornament of *B. coloradensis*, though by no means so well preserved as one might wish in the Rockwood specimens, is clearly of the tuberculate order; here and there the tubercles appear to be more or less confluent, but nowhere do they fuse into vermiculating ridges, as in other American and some foreign species. The center of ossification in the posterior

ventrals is situated near the outer margin some distance behind the middle of the plate; in advance of this point the vascular canals radiate in all directions between parallel with and at right angles to the median line, but behind it they are crowded together and directed obliquely backward. This condition is apparent in all three individuals, and is indicated by the shading in fig. 1.

The ventral armour of the best preserved individual, that shown in the figure, has a width across the middle portion of 8·5^{cm}, and an estimated total length of about 14^{cm}. The largest

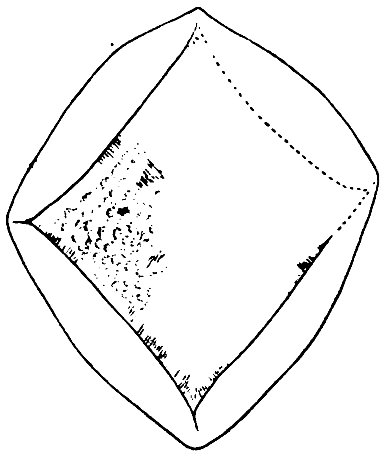


Fig. 3.—***Bothriolepis major*** **(Ag.). Median ventral, × ½.**

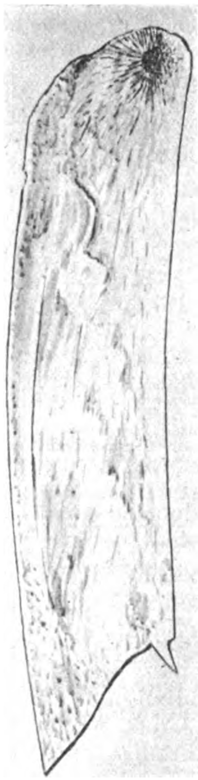
example of *B. canadensis* with which the writer is acquainted displays a corresponding width of 10^{cm}, and length of 16^{cm}. *B. major* attains even larger dimensions, the carapace and head, according to Traquair, measuring sometimes 1·5 feet. The length of the pectoral appendages in the new form appear to be intermediate between those of the above-named species, but their covering plates are not sufficiently well preserved to permit of detailed comparisons. In the drawing, the distal end of one of the appendages, which is not serrated, and also a portion of the left posterior ventral have been added from a second specimen, otherwise the parts are shown as they occur in a single individual. The outline of the median and posterior ventrals is perfectly distinct, but the remaining sutures, including those of the pectoral members, are unfortunately obliterated. A very unusual feature in this genus is the obtusely rounded posterior margin of the plastron. On the whole, it appears probable that the relations of the Colorado

species are closer to the European *B. major* than to any other member of the genus.

Needle Mountains Quadrangle.

The principal fossiliferous localities of the Elbert formation, and at the same time historically the most interesting, are those occurring along the eastern edge of the Endlich mesa, *Devon Point* being the name given by Dr. Cross to the most productive. Here the fish remains are distributed throughout beds near the base, and also near the top of the section, being in fact so abundant as almost to justify the name of "fish-bed." And yet the variety of forms represented is surprisingly meagre. Portions of Bothriolepis armour are plentiful, probably not more than two species being represented, however. In addition there occur scales belonging to two species of Holoptychius, but this is all. No Dipnoan remains, and no Arthrodires, which invariably accompany Bothriolepis and Holoptychius in the Upper Devonian, are at present known from this locality. In fig. 4 is shown a weathered fragment of a pectoral limb of Bothriolepis, the external layer having been removed, and the bone substance appearing in longitudinal section. No characters remain for determining the species, yet its large size appears to indicate an identity with *B. coloradensis*. Some of the smaller fragments display an ornament of vermiculating ridges similar in all respects to that observed in *B. leidyi*, from the Catskill of Pennsylvania; and in the absence of more decisive evidence, they may be provisionally referred to that species.

4



The scales of Holoptychius shown in figs. 5 and 6 are preserved in the form of impressions, but the characteristic tubercles and ridges of the exposed surface are clearly indicated. Both of these scales fall within the limits of *H. giganteus*, according to the original definition of that species as given by

Agassiz, allowance having been made by him for variation amongst scales belonging to different parts of the body in the same fish. The species was subsequently divided by Newberry, who included under the name of *H. tuberculatus* those scales in which the tubercles remained distinct, and were not fused into continuous, longitudinal ridges. As for Newberry's *H. americanus*, this resembles Agassiz's species in having the ridges irregularly tortuous, and more or less interrupted and branching, hence it will be seen that the precise determination

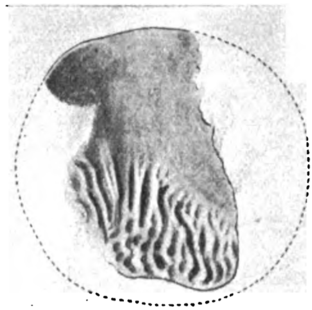


FIG. 5. — *Holoptychius giganteus* Ag. Scale, × ¼.

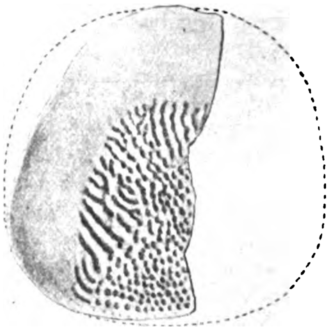


FIG. 6. — *Holoptychius tuberculatus* Newb. Scale, × ½.

of detached scales is a matter of some difficulty. Probably we shall not err greatly in identifying the original of fig. 5 as *H. giganteus* Ag., and that of fig. 6 as *H. tuberculatus* Newb.

Engineer Mountain Quadrangle.

From Station No. 209, a locality on Little Cascade Creek, one half mile south of Columbine Lake, Engineer Mountain Quadrangle, a single finely tuberculated plate was obtained by Dr. Cross, which appears to be a posterior ventral of some Arthrodire, of about twice the size of the type species of Coccosteus. Occurring as it does in the detached condition, and more or less injured by weathering, even an approximate determination is impossible.

Pitkin County.

The few fragments obtained by Mr. Spurr from the vicinity of Aspen are poorly preserved, and specifically indeterminable.* Two or three finally tuberculated plates are probably to be regarded as of Arthrodire nature, and the presence of

* This remark applies only to the small portion of Mr. Spurr's collection which has as yet come under the writer's observation. At the time this article was written, it was not practicable to obtain access to the remaining

Dipnoans is indicated by certain smooth scales displaying their characteristic perforations. These latter, however, are noteworthy for furnishing the only indication we possess at present of the occurrence of Lung-fishes in the Colorado Devonian.

General Conclusions.

It has already been remarked that the remains brought to light by Dr. Cross are indicative of an Upper Devonian horizon. No other conclusion seems possible in view of the fact that Bothriolepis is an exclusively Upper Devonian genus, and the greater number of Holoptychius species occur in beds of the same age. The two species of the former genus already known from this country, and dozen or so of Holoptychius, are limited to the Chemung and Catskill groups of New York and Pennsylvania. One species of Bothriolepis (*B. canadensis* Whiteaves), and one of Holoptychius, have been described from the Upper Devonian of the Province of Quebec, Canada. These genera are represented abroad by various species found in the Upper Old Red Sandstone of Scotland, and in the Upper Devonian of Belgium and Northwest Russia. The vertebrate fauna of which they form part is composed of Ostracophores, Arthrodires, Dipnoans, Crossopterygians and Elasmobranchs, and it is interesting to note that all of these groups with the exception of the last-named are represented in the Colorado Devonian.

Regarding the origin of the Colorado fauna, little can be said with positiveness. The new species of Bothriolepis appears to be most closely related to *B. major* of Scotland and Russia, and if the fragments showing vermiculated ornamentation are correctly interpreted as belonging to *B. leidyi*, this identification, with that of *Holoptychius giganteus*, place the fauna in relation with the Catskill of Pennsylvania. The Chemung-Catskill of the eastern States betrays an unmistakably European origin, but there is good reason to suppose that a barrier existed between the eastern and western regions during the late Devonian, since neither Holoptychius nor Bothriolepis remains have been found west of New York and Pennsylvania. From this latter region also, the Upper Devonian Ptyctodonts and Dipnoans of Iowa and contiguous States were entirely excluded. Assuming that there was no connection between the eastern and western areas toward the close of the Devo-

specimens, nor to the interesting material collected by Dr. C. D. Walcott from the lower Kanab canyon of Arizona in 1879, owing to the limited storage facilities of the Museum, and absence from Washington of the proper custodians. Mr. Walcott's only publication in regard to the Kanab material is to be found in this Journal [3], vol. xx, p. 224.

The Aspen material is briefly described by Dr. G. H. Girty, in vol. xxxi, p. 20, of U. S. G. S. Monographs (J. E. Spurr: *Geology of the Aspen Mining District*). Without having actually seen the teeth, which are there provisionally referred to "Rhizodus," a Carboniferous genus, we may be permitted to hazard the presumption of their belonging to Holoptychius.

nian, it is difficult to understand how members of the Chemung-Catskill fauna could have reached Colorado, unless they came by some southern route as yet unknown. On the other hand, a Eurasiatic origin by way of Behring Straits cannot be regarded as an impossibility, nor even as an improbability, since the invertebrate fauna of the superjacent formation has been shown by Dr. Girty* to be "not closely similar to the faunas of the eastern and central United States," but exhibits, in his opinion, "a closer parallel with the Devonian of the Ural Mountains."

Attention should also be called to Professor Calvin's observations on the Devonian system of Iowa, which go to show that the eastern and western areas were geologically isolated. According to this author,† "the eastern Devonian faunas probably migrated from the northeast along the eastern border of the continental nucleus, while the western faunas of the same period seem to have come from the northwest along the western border of the Devonian continent." He also points out that the Iowa Devonian fauna is related in some respects to that occurring at the Ramparts of the Mackenzie River, and the present writer has commented on certain resemblances between its vertebrate constituents and the corresponding fauna of Russia.

For the present, the question as to the origin of the vertebrate fauna of the Colorado Devonian must be considered as problematical, and one which will require considerable further evidence and investigation before it can be answered satisfactorily. It is evident that the remains thus far obtained by Dr. Cross constitute not only an important paleontological discovery, but open up problems of distribution, and others of a geological nature, which are worthy of careful study.

Harvard University, Cambridge, Mass.

EXPLANATIONS OF FIGURES.

FIGURE 1.—*Bothriolepis coloradensis* sp. nov. Elbert formation; Rockwood, Col. Ventral armour, ¼ natural size. *avl*, Antero-ventro-lateral; *mo*, Median ventral; *pvl*, Postero-ventro-lateral plates. (U. S. Nat. Mus.)

FIGURE 2.—*Bothriolepis major* (Ag.). Upper Old Red Sandstone; Elgin, Scotland. Ventral armour, seen from the visceral aspect, × ⅝. (Original in Mus. Comp. Zoöl. at Cambridge.)

FIGURE 3.—*Bothriolepis major* (Ag.). Median ventral, × ½. *Ibid.*

FIGURE 4.—*Bothriolepis coloradensis* (?) sp. nov. Fragmentary pectoral appendage, × ½. Elbert formation; Devon Point, Colorado.

FIGURE 5.—*Holoptychius giganteus* Ag. × ½. Same locality.

FIGURE 6.—*Holoptychius tuberculatus* Newb. × ½. Same locality.

* The Carboniferous Formations and Faunas of Colorado (Profess. Paper U. S. Geol. Surv., No. 16, p. 162), 1903.

† Ann. Rept. Iowa Geol. Surv., vol. VIII (1897), p. 221. One may compare also the following important papers on Devonian paleontology: Schuchert, C., On the Faunal Provinces of the Middle Devonic of America, etc. (Amer. Geol., vol. xxxii, pp. 137–162), 1903. Williams, H. S., The Correlation of Geological Faunas (Bull. U. S. Geol. Surv., No. 210), 1903.

ART. XXX.—*On some Fossil Turtles belonging to the Marsh Collection in Yale University Museum;* by O. P. HAY. (With Plates XI–XVI.)

THE present paper is the result of a study of some of the extinct turtles in the collections of vertebrate fossils brought together by Professor O. C. Marsh. The privilege of making the investigation was first granted by the late Professor Charles E. Beecher; after his death it was renewed by the acting curator of the collection, Professor L. V. Pirsson. For assistance and courtesy the writer's thanks are due to all the officers having connection with the department of vertebrate paleontology in Yale University. The negatives from which several of the plates have been prepared were furnished by Dr. George R. Wieland. The wash drawings were made by Mr. Erwin Christman, of the American Museum of Natural History.

Further remarks on the species here treated and additional illustrations will, it is hoped, be presented in the writer's forthcoming monograph of the fossil turtles of North America.

Baëna marshi sp. nov.

Plate XI; Text-figure 1.

The type of this species was collected in 1889, by Professor J. B. Hatcher, in the Laramie deposits of Converse County, Wyoming, between Buck and Lance creeks.

The specimen has suffered considerable damage. There are present the central region of the carapace and most of the left side, the greater portion of the plastron, and the matrix forming a cast of the interior of the shell. The length of the shell can be determined only approximately. It must have been at least 300^{mm}, with a breadth of 220^{mm}.

On account of the obliteration of the sutures of the carapace, its structure cannot be made out. The bones along the median region have a thickness of from 10 to 13^{mm}. The outer surface is smooth. The sulci between the various dermal scutes are narrow and shallow, and in many places cannot be traced. The second, third, and fourth vertebral scutes varied in width from 64 to 70^{mm}.

The posterior extremity of the plastron is missing; hence the length of the plastron cannot be accurately determined, nor the form of the posterior margin. The total length, however, must have been close to 260^{mm}. The following table presents the most important dimensions. In order that the distinctness of the species from *B. hatcheri*, which is from the same deposits and locality, may be appreciated, the dimensions of the plastron of the latter are also given.

Dimensions.	*Baëna marshi.*	*Baëna hatcheri.*
Length of plastron..........	260±	305
Width of bridge............	120	115
Length of anterior lobe.....	70	106
Width of anterior lobe	95	115
Length of posterior lobe	65±	98
Width of posterior lobe	90	120

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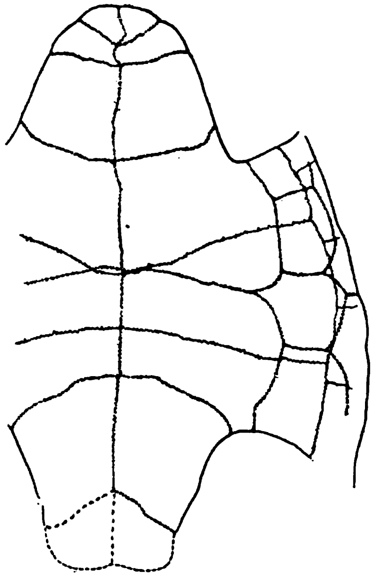

FIGURE 1.—*Baëna marshi.* Diagram of plastron.

It will be observed that, while the plastron of *B. hatcheri* is considerably longer, the bridge is slightly shorter. Further, the lengths of the anterior and posterior lobes of *B. marshi* are much less in proportion to the total length of the plastron than they are in *B. hatcheri.*

The central region of the plastron is concave. This may indicate that the individual was a male. The mesoplastra are large, wedge-shaped bones. They meet along the midline for a distance of 23^{mm}, and their outer ends are 65^{mm} wide.

The following are the antero-posterior widths of the various plastral scutes: Intergulars, 17^{mm}; gulars, 10^{mm}; humerals, 46^{mm}; pectorals, 50^{mm}; abdominals, 47^{mm}; femorals, 53^{mm}; anals, about 45^{mm}. On the bridges there are four inframarginals, of which the inguinal is the largest, and the axillary somewhat the smallest.

This species differs from *B. hatcheri* in the greater thickness of the bones of the carapace and in the shorter lobes of the plastron. It is named in honor of the late Professor Othniel C. Marsh.

Baëna cephalica sp. nov.

Plate XII, Figures 1–3.

The name *Baëna cephalica* is given to a fine skull which belongs to the Yale University Museum, and which was collected in the Laramie deposits of Converse County, Wyoming, by Professor J. B. Hatcher. The specimen bears Professor Marsh's receipt number 2110.

In general form the skull is broad behind, and flat above, with pointed snout. The length from the snout to the occipital condyle is 67^{mm}; to the end of the supraoccipital spine, 74^{mm}. The greatest breadth, just in front of the tympanic chambers, is 65^{mm}. From these chambers the width diminishes to the snout. There is first a convexity in the outline, which terminates at the hinder end of the maxilla; a second and longer one which ends behind the premaxilla, and a third one which ends at the premaxillary symphysis. The flat upper surface of the skull descends each way to the perpendicular sides. The sides of the face about the orbits look upward and outward, as well as forward. The tympanic opening is nearly circular, 19^{mm} in perpendicular and 15^{mm} in horizontal axis. The orbit is circular and small, its diameter being 14^{mm}. The nasal opening, as seen from in front, is somewhat heart-shaped, and is directed upward and forward. From the orbit to the tympanic opening is 24^{mm}; from the nares to the orbit is 10^{mm}.

The temporal region is roofed over, not so extensively as in some undescribed Bridger skulls of the same genus. On each side of the supraoccipital, this roof is excavated as far as a line joining the anterior borders of the tympanic chambers. The hinder end of the postfrontal is interposed between the parietal and the squamosal.

In general, the sutures of this skull are very distinct, but no trace has been found of those between the frontals and the parietals. There are distinct nasals. The prefrontal of each side joins the postfrontal, so that the area of the frontals is excluded from the orbit. The postfrontal is large, having a length of 32^{mm}. The jugal is small, having a length of only 8^{mm} and a height of 15^{mm}. The squamosal forms the hinder border of the tympanic opening. Superiorly it has a thin crest, a relic of the former backward extension of the temporal roof. There is a prolongation of the tympanic chamber into this bone. The lower border of the zygomatic bar is considerably exca-

vated. Seen from the side, the maxilla is convex on its lower border. The premaxillæ are distinct from each other and from the maxillæ. At the symphysis they are only 3^{mm} high, but at their union with the maxillæ, 10^{mm} high. As in the Bridger species, there are distinct lachrymal bones. They occupy the position of the descending portion of the prefrontals of other turtles, coming in contact with the vomer.

As seen from below, the maxilla has a broad masticatory surface, its width from the inner border to the cutting edge being 14^{mm}. The inner border of this surface is furnished by the palatine bone. The latter forms the whole of the outer border of the choana. The masticatory surface does not extend forward on the premaxilla. In front of the choanæ there is a deep groove, which anteriorly expands on the lower surface of the premaxillæ. Postpalatine foramina are present.

The pterygoids come in short contact with the maxillæ. They have distinct ectopterygoid processes. Where the posterior part of the palate is constricted, it is 18^{mm} wide. The pterygoids extend backward to the posterior border of the pedicel of the quadrates, thus separating the latter widely from the basioccipital and basisphenoid. There is a considerable groove on each side between the quadrate and the median bones of the base of the skull. The pterygoids join at the midline for some distance in front of the basisphenoid. On each side of the latter, about the middle of its length, is a foramen.

The pedicels of the quadrates are short. The surface for articulation with the lower jaw is deeply concave from side to side; nearly plane from front to back.

The quadrate bone is notched behind for the passage of the stapedial rod.

There appears to have been a system of epidermal scutes covering the upper surface of the skull. Not all the areas occupied by these can be made out with certainty, but some of them are quite distinct. A pair of these seems to have occupied the space between the orbits. Behind each of these is a smaller one which lies over the hinder border of the orbit. A very large scute, or more probably a pair of them, covers the area of the frontal bones and overlaps on the parietals. The posterior half of this scute or scutes is separated by two scutes occupying the midline. One of these, the anterior, is small and circular; the other is elongated and extends backward on the supraoccipital processes of the parietals. It is, of course, possible that the latter scute was divided along the midline.

The study of this skull confirms the view of Dr. George Baur, drawn from the skull of *Compsemys plicatula*, that there are in the skulls of the Amphichelydia few pleurodiran characters. Nasals are indeed present, but they can hardly be

regarded as distinctive, since there are Cryptodira (Porthochelys) which possess nasals. A short supraoccipital spine is very general among the Pleurodira. The character which especially separates the latter group from the Cryptodira is found in the very broad pterygoids, the posterior ends of which do not separate the quadrates from the basioccipitals. In Baëna, as shown in the present skull and in others from the Bridger beds not yet described, the pterygoids are disposed in the same way as in the Cryptodira.

It appears, in fact, that a considerable number of characters exist in the skulls of Baëna, which belong also to the Athecæ. These are found in the short supraoccipital spine, the large postfrontals, the exclusion of the frontals from the orbits, and the participation of the basioccipital in the formation of the foramen magnum.

The nasals, the lachrymals, and the extensive temporal roof may be regarded as primitive characters.

In Baëna, undoubted pleurodiran characters are seen in the presence of a mesoplastron and in the structure of the cervical vertebræ. The suborder Amphichelydia must thus be regarded as securely founded.

Baptemys wyomingensis Leidy.

Plate XIII, Figures 1–3; Text-figure 2.

Baptemys wyomingensis, Leidy, J., Proc. Acad. Nat. Sci. Phila., 1870, p. 5; Contr. Ext. Fauna West. Terrs., 1873, p. 157, pl. xii, pl. xv, fig. 6.

This species is represented in the Marsh collection by a specimen which was collected in the year 1870, in the Bridger beds, near Millersville, Wyoming. The carapace is almost entire, but somewhat crushed and distorted. The plastron is intact. The nearly complete skull is present; likewise, some of the limb bones. The specimen bears the number 484. It is most valuable on account of furnishing the hitherto unknown skull and the not well-known anterior lobe of the plastron.

When this example is compared with the type some differences are observed, but these are not regarded as of specific value. The most important of these differences is the presence of four, instead of three, inframarginal scutes on each of the bridges.

The only portion missing from the skull is the roof of the orbits and the nasal cavity. This deficiency is fortunately supplied by a skull collected during the year 1903 by the American Museum expedition into the Bridger beds near Fort Bridger.

The skull is wedge-shaped, being broad behind and pointed in front. The length from the snout to the occipital condyle is 67^{mm}; to the end of the supraoccipital spine, 88^{mm}. The

width at the upper border of the tympanic cavity is 58^{mm}. There is no roof over the temporal region, and there is no parieto-squamosal arch. The postorbital arch is but little more than 7^{mm} wide. The zygomatic bar is excavated on its lower border. The interorbital space, as shown by the American Museum specimen, is 23^{mm} wide. The orbits are large, having an antero-posterior diameter of about 20^{mm}. The nares, as shown by the specimen last mentioned, have a perpendicular diameter of 16^{mm}. The upper jaw is convex along its cutting edge, rising in front so as to form a median notch. This edge is sharp throughout its length. In the Yale specimen, the lower jaw conceals a portion of the palate near the cutting edge, but this region is exhibited in the American Museum specimen. Running parallel with the posterior half of the cutting edge, and separated from it by a deep furrow, is a sharp dentated ridge, which has a length of 12^{mm}. When the jaws are closed this ridge fits into a groove in the lower jaw.

The choanæ are far forward. The roof of the mouth is vaulted, not greatly unlike that of Testudo. The vomer appears to have extended backward nearly to the pterygoids. The distance across the palatines at their posterior ends is 20^{mm}. The distance across the constricted portion of the pterygoids is 13^{mm}. There are small postpalatine foramina. The outer border of the palatine bone has not been traced with certainty. In the specimen in the American Museum there appears to be a suture running along the bottom of the groove on the outside of the dentated ridge mentioned above. If this is really the case, this ridge lies on the palatine bone.

The tympanic cavity has its posterior wall open, forming a channel for the passage of the stapedial rod. The sutures between the bones of the skull are closed, and some of them can be traced only with difficulty. There appear to have been no nasals. As shown by the American Museum specimen, the frontals are shut out from the borders of the orbits.

The lower jaw appears to have formed a slight beak in front. The anterior half of the efficient border forms a cutting edge which shears against that of the maxilla. Posteriorly the edge divides so as to produce two ridges which enclose between them a deep groove about 4^{mm} wide. It is this groove which receives the dentated ridge of the palate.

Portions of the hyoid apparatus remain clinging to the base of the skull. This apparatus resembles closely the same organ in *Chrysemys elegans*, and is much unlike that of *Dermatemys*.

Text-figure 2 shows the form of the plastron, and this agrees with that of the specimen in the American Museum. Leidy (Contr. Ext. Fauna West. Terrs., pl. xv, fig. 6) has figured the anterior end of a plastron which is truncated and slightly exca-

vated. This may be an individual variation, or it may indicate a distinct species. In all the known specimens of this species the intergular and gular scutes are absent, and the humerals extend forward to the front of the plastron.

A comparison of the skull of this species with that of *Dermatemys mawii*, as described and figured by Bienz (Rev. suisse de Zool., iii, 1895, p. 61, pl. ii, figs. 1–5) shows that the two are similar in general form and in the absence of a temporal roof. The structure of the upper and lower jaws is quite dif-

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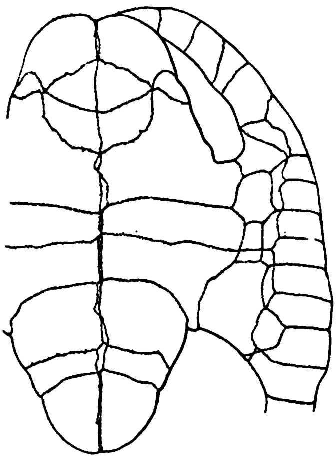

FIGURE 2.—*Baptemys wyomingensis*. **Diagram of plastron.**

ferent in the two genera. In Dermatemys the choanæ are underfloored by the palatal plates of the maxillæ and are pushed well backward. In Baptemys they are far forward in the vaulted palate.

Chrysemys wyomingensis Leidy.

Plate XIV ; Text-figures 3, 4.

Emys wyomingensis Leidy, J., Proc. Acad. Nat. Sci. Phila., 1869, p. 66; Contr. Ext. Fauna West. Terrs., 1873, pp. 140, 340, pl. ix, figs. 4, 5, pl. x, figs. 1, 2. Hay, O. P., Bibliog. and Cat. Foss. Vert. N. A., 1902, p. 448.

In the collection of fossil vertebrates made by Professor Marsh in the year 1874, there is an unusually interesting specimen of turtle. This is a nearly complete shell, and was obtained in the Bridger beds at Millersville, a point a few miles east of Fort Bridger, Wyoming. It is referred without doubt to the species above named. It is interesting from the fact that it possesses a number of supernumerary structures. That is, it has nine neurals, instead of eight; ten pairs of costal

plates, instead of eight pairs; twelve pairs of peripheral bones, instead of eleven pairs; six vertebral scutes, instead of five; five pairs of costal scutes, instead of four pairs; and twelve pairs of marginal scutes, instead of eleven pairs. There is no doubt regarding the presence of any of these extra bones and scutes, since all the sutures and sulci are very distinct.

A comparison of this carapace with Leidy's figure of *Emys wyomingensis* shows that the whole anterior portion agrees with that figure, only such deviations as might be expected in two individuals of the same species being present. The posterior third, however, leads one into difficulties.

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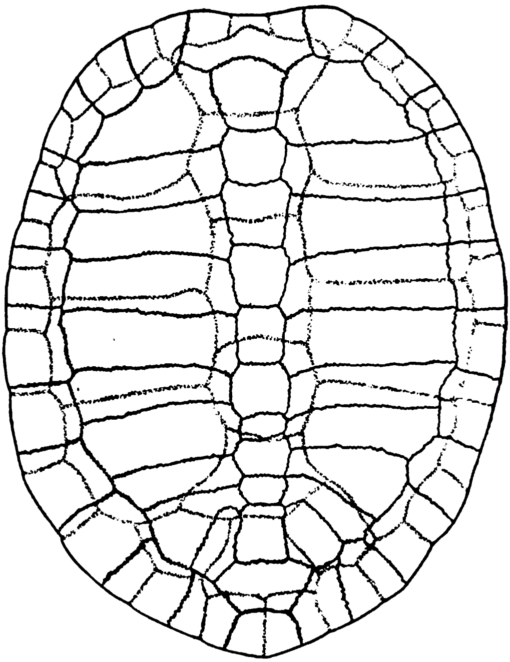

FIGURE 3.—*Chrysemys wyomingensis.* Diagram of carapace of individual possessing supernumerary structures.

The normal number of costal plates is, of course, eight pairs. In some of the living species of North American Trionychidæ the costals are reduced to seven pairs. Dr. Boulenger has stated that in some fossil marine turtles there are nine or ten pairs of costals, but he has not mentioned the species. Such cases may occur, but it is doubtful that they are normal forms. Mr. L. M. Lambe (Contr. Canad. Palaeont., iii, 1902, p. 42, fig. 7) has described as a new genus and species *Neurankylus*

eximius, which has nine pairs of costal plates. Dr. George Baur referred to a specimen of *Malacoclemmys geographica* having nine costals. Dr. Boulenger, in his Catalogue, p. 187, states that in a specimen of Pelomedusa he found nine pairs of costal plates; in another, nine plates on one side and eight on the other. Is it possible, therefore, to determine which costal and peripheral bones, and which vertebral, costal, and marginal scutes, in the specimen at hand, are the intercalated ones?

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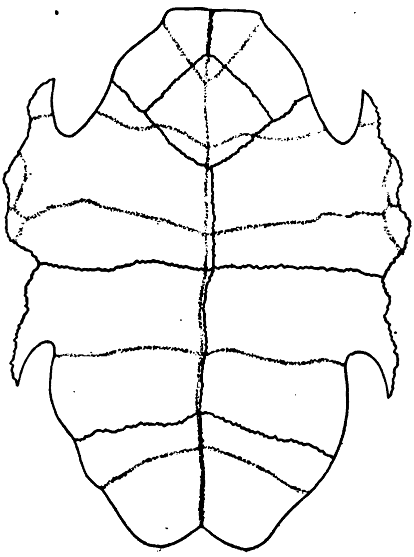

FIGURE 4.—*Chrysemys wyomingensis*. Diagram of plastron of same individual as that of figure 3.

It seems to the writer that there can be no question that the six anterior neural bones and the six anterior pairs of costals, together with the peripherals in contact with the latter, correspond exactly with the six anterior neurals, the six anterior pairs of costals, and the contiguous peripherals, of the type specimen of *Chrysemys wyomingensis*, or, indeed, of any other member of the Emydidæ. It appears to be quite as certain that the seventh pair of costals corresponds with the seventh pair in other emyds. Each is crossed at its upper end by a portion of the longitudinal sulcus, and is in contact with a neural, probably the seventh, and with that behind it.

If, now, one begins at the posterior margin of the shell and works forward, certain conditions may be established. As usual, a pygal peripheral is present. In front of this comes a

broad hexagonal suprapygal, the homologue of which is partly shown in Leidy's figure of the type, and is fully shown by a specimen in the American Museum of Natural History. In all three examples mentioned, this suprapygal is crossed near its anterior end by a sulcus bounding the supracaudal scute in front. In Leidy's type, in front of this suprapygal is another which widens backward. A similar bone is found in the American Museum specimen and in the one here described; but, in both of the latter, the bone is somewhat longer, and is crossed by a transverse sulcus. In Leidy's type, the sulcus crosses on the neural immediately in front,—the eighth.

The last pair of costals in the Yale specimen has all the characteristics of the eighth pair in Leidy's type and in the American Museum specimen. They come in contact with the two suprapygals, are crossed at their anterior ends by a transverse sulcus, and are occupied in their length by the lateral sulci of the hindermost vertebral scute. In the specimen here described these costals do not indeed come in contact with the hindermost neural; but it is no unusual thing for the last pair of costals to be pushed out of contact with this neural, or the real eighth neural may be suppressed.

It is concluded, therefore, that the intercalated costal plates of the present specimen are the eighth and the ninth from the front of the carapace.

Since there is only one extra neural present, it appears to be impossible to determine whether this is the eighth or the ninth from the front. It may be, however, as already suggested, that the true eighth has been suppressed, and that the eighth and the ninth, counting from the front, are both intercalated.

It is likewise uncertain which is the intercalated peripheral, the tenth or the eleventh of this specimen; but it is more likely the tenth, since it is in contact with both the intercalated costals.

As to the vertebral scutes, the first, second, and sixth seem clearly to correspond with the first, second, and fifth, respectively, of a normal emyd. It appears to be quite as certain that the anterior portion of the fourth corresponds with the same portion of the fourth of any other emyd; and again that the posterior portion of the fifth is homologous with the posterior portion of the fourth vertebral of ordinary turtles. Does not this evidence lead to the conclusion that no new scute has been intercalated, but, rather, that the area occupied by the fourth scute in a normal turtle, having been greatly enlarged, has become divided by a transverse sulcus? In the same way the extra costal scute on each side, as well as the extra marginal, may be explained.

The region immediately in front of the most anterior suprapygal presents various evidences of having suffered disturbance.

Notwithstanding the possession of ten pairs of costal plates, this specimen is not elongated, as one might expect it to be. Indeed, the width is relatively greater than in the specimen in the American Museum.

The plastron appears in no way different from that of the other known specimens of the species. It is quite complete, and a pen drawing showing its structure is here presented.

The total length of the carapace is 325^{mm}; the width is 240^{mm}. Leidy's specimen was at least 330^{mm} long and close to 235^{mm} wide.

Hadrianus majusculus sp. nov.

Plate XV; Text-figure 5.

The shell on which the present species is based was received at the Yale University Museum late in the year 1876. It bears Professor Marsh's receipt number 927. The label has

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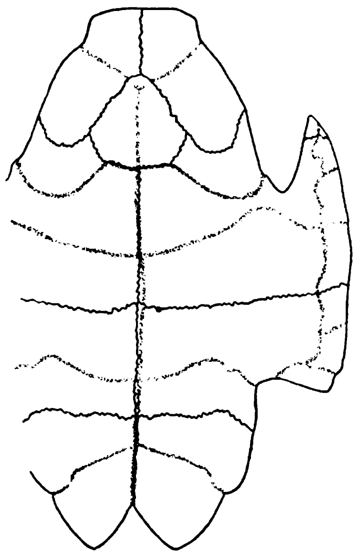


FIGURE 5.—*Hadrianus majusculus*. Diagram of carapace.

the following record: "Turtle from foot of bluff, west side of Murderer's Gap. Nov. 19, 1876. D. Baldwin." Another label states that the specimen came from the "Eocene Bad Lands, Gallina, New Mexico." This locality appears to be in Rio Arriba County, New Mexico. The deposits doubtless belong to the Wasatch epoch.

The upper portion of the shell and one side of it are somewhat damaged. The length of the carapace is 530^{mm}; the greatest breadth was at least 440^{mm}. In form the shell was rather high and vaulted. Over the limbs the peripheral bones are considerably flared upward. The posterior border is rounded and scalloped. The free borders of all the peripherals have acute edges. The form and dimensions of many of the neurals cannot be determined. There appear to have been three suprapygals, the penultimate of which is bifurcate, as in the species of Testudo. The anterior four or five costal plates are alternately narrow and wide, but the proximal and the distal ends of each are of about the same width, thus differing from the costals of Testudo.

The peripheral bones, conspicuously those over the bridges, are much higher than those in the Bridger species, *H. corsoni.* They rise about 90^{mm} above the slight carina which joins the third with the seventh peripheral. The sulci which bound the epidermal scutes are narrow and shallow, but they run in rather deep grooves in the bones. There are two very distinct supracaudal scutes, a right and a left.

The plastron has about the same length as the carapace. There is a distinct lip in front. The rear of the plastron is deeply notched. The antero-posterior extent of the pectoral scutes is considerably greater than in *H. corsoni.*

The large peripherals and the broad pectoral scutes especially distinguish this species from those of Hadrianus hitherto described.

Professor Cope has referred some remains of this genus from the Wasatch of New Mexico to *H. corsoni*, but his specimens were too fragmentary for accurate determination.

Hadrianus majusculus is interesting because of its being the oldest known member of the Chersites, or Testudinidæ.

Testudo brontops Marsh.

Text-figures 6, 7.

Testudo brontops Marsh, O. C., this Journal (3), xl, 1890, p. 179, pl. viii; Vert. Foss. Denver Basin, in Mon. U. S. Geol. Surv., xxvii, 1897, pp. 523, 527, figs. 95, 96. Dana, J. D., Manual Geol., 1896, p. 901, fig. 1516. Hay, O. P., Bibliog. and Cat. Foss. Vert. N. A., 1902, p. 451.

This species has already been briefly described by Professor O. C. Marsh, as cited. The writer has been enabled to study with some care this fine specimen, and here presents diagrammatic figures illustrating the structure of the carapace and the plastron. The structure has been somewhat obscured by crushing, especially along the midline of the carapace.

The length of the carapace is 711^{mm}; the greatest breadth is 651^{mm}. The carapace is truncated in front and broadly

rounded behind. Over the limbs the peripheral bones are considerably flared upward. The sutures separating the nuchal from the first peripherals cannot be traced with certainty. The greatest width of the bone is 175^{mm}; and the length along the midline, 150^{mm}. The first neural bone is oval; the second and fourth, octagonal; the third, hexagonal. The fifth was probably hexagonal, but it is somewhat crushed. The sixth, seventh, and eighth are approximately hexagonal. The anterior suprapygal is bifurcate. The costals of the second, third, fourth,

6 7

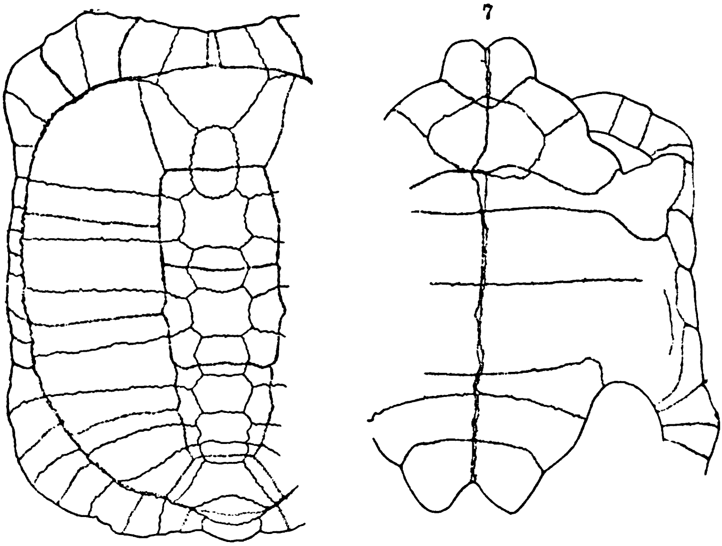


FIGURE 6.—*Testudo brontops.* Diagram of carapace.
FIGURE 7.—*Testudo brontops.* Diagram of plastron.

fifth, and sixth pairs are alternately narrow and wide at their proximal ends, and alternately wide and narrow at their distal ends. The following table gives the dimensions of the costals, excluding the first:

Costal.	Width at proximal end.	Width at distal end.
2	56	106
3	100	73
4	56	90
5	94	56
6	61	95
7	40	75
8	43	62

The second and third vertebral scutes had a width of about 190^{mm}. The sulci of the region of the bridge ran in deep valleys, thus giving a scalloped appearance to the border.

The plastron is quite concave. The lip of the anterior lobe projected boldly beyond the general border of the plastron and beyond the front of the carapace. There is a considerable notch in the posterior end of the plastron. The pectoral scutes are about 55^{mm} wide at the midline; the abdominals, 240^{mm}.

This large and fine species was found in the Titanotherium beds of Indian Creek, Pennington County, South Dakota. It is especially interesting because of its being the oldest known species of the genus. Although so old, it appears to have been as highly differentiated in all respects as are the modern forms of the genus.

Aspideretes beecheri sp. nov.

Plate XVI.

Trionyx foveatus Baur, G., Proc. Acad. Nat. Sci. Phila., 1891, p. 418 (not Leidy).

In the Marsh collection there is a fine specimen of a Trionychid to which the above name is given. It was collected in the year 1889 by Professor J. B. Hatcher and Dr. C. E. Beecher, in the Laramie beds of Converse County, Wyoming, on the east side of Lance Creek. The specific name is given in honor of one of the collectors, Dr. Beecher, whose untimely death has wrought such injury to the science of paleontology.

This specimen was examined by Dr. George Baur and identified by him as Leidy's *Trionyx foveatus*. The present writer does not agree with this determination. Dr. Leidy's species was based on rather scant material, but the ornamentation of the costal bones is characteristic and has led to the identification of the species by Mr. L. M. Lambe (Geol. Surv. Canada, Summ. Rept., 1901, p. 81, pls. i, ii; Contr. Canad. Palaeont., iii, 1902, p. 33, pl. i, figs. 1, 2) in finely preserved and quite complete remains. The latter indicate a Trionychid quite different from the one here described.

The type of *A. beecheri* presents the limbs nearly complete, a portion of the neck, the tail, the shoulder girdle, a large portion of the carapace, and the whole of the plastron.

The carapace had a length close to 325^{mm} and a width of 310^{mm}. At each end of the nuchal, the border has been somewhat excavated. The lateral margins are slightly sinuous, and the posterior border has probably been slightly concave.

The outer ends of the nuchal appear to have overlapped the first costal. The nuchal has its whole upper surface covered with a sculpture like that of the costals. There is a preneural bone, whose anterior border has occupied a notch in the hinder border of the nuchal. The author has elsewhere proposed the name Aspideretes for the Trionychidæ possessing a pre-

neural, the type of the proposed genus being *Trionyx gangeticus* Cuvier. The first neural of *A. beecheri* is hexagonal, with the narrow end directed forward. There is present a second neural of similar form and a portion of a third. The remaining neurals are missing. In all probability there were eight pairs of costal plates, but the eighth is represented in this specimen by the free portion only of the corresponding rib.

The sculpture of the carapace consists of a network of ridges enclosing rather deep pits. Usually these pits are without definite arrangement, but on the distal ends of the costals they arrange themselves in rows parallel with the free borders of the carapace. The walls surrounding the pits rise abruptly from the bottoms of the latter; whereas, in *A. foveatus*, the walls slope upward gradually from the centers of the pits. Furthermore, in the latter species, the pits on the proximal ends of the costals are likely to have quite wide flat spaces between them.

The plastron is complete. The entoplastron is truncated in front, with a slight notch at the midline. The branches include between them less than a right angle. The epiplastra are broad at their anterior ends. They resemble greatly the same bones in *Aspidonectes muticus*. The hyoplastra are not coössified with the hypoplastra. Between the inner ends of the hyoplastra is a large fontanelle which is bounded in front by the entoplastron. Between the inner ends of the hypoplastra is another fontanelle which extends backward to the xiphiplastra. There is no fontanelle between the latter bones. The bridge, where narrowest, has a width of 64^{mm}.

The whole lower surface of the hyoplastra, the hypoplastra, and the xiphiplastra, is covered with a sculpture like that of the carapace, except that it is finer.

The cervical vertebra seen in Plate XVI is probably the fifth. Its length is about 60^{mm}. Seven caudal vertebræ are preserved, forming a series 122^{mm} long; but there were others which have been destroyed. They are very similar to those of *Aspidonectes spiniferus*. The shoulder girdle, the fore limbs, the pelvis, and the hind limbs present no important differences when compared with those of modern Trionychidæ.

It appears probable that this individual was a female of mature age.

The U. S. National Museum possesses a Trionychid which was collected by one of Professor Marsh's parties, while he was vertebrate paleontologist to the U. S. Geological Survey. It was obtained in Converse County, Wyoming, and is referred to *A. beecheri*. It shows the carapace to have been high and convex; also, that it had a preneural, six neurals, and eight pairs of costal plates.

EXPLANATION OF PLATES.

Plate XI.

Baēna marshi Hay; view of the plastron. × $\frac{1}{3}$.

On the left side of the figure is seen a portion of the matrix which filled the shell and from which the bone has been removed. On the opposite side, posteriorly, is seen some matrix filling the inguinal notch. From photograph.

Plate XII.

Baēna cephalica Hay.

Figure 1.—Skull seen from above. × $\frac{3}{4}$.
Figure 2.—Skull seen from below. × $\frac{3}{4}$.
Figure 3.—Skull seen from left side. × $\frac{3}{4}$.

Plate XIII.

Baptemys wyomingensis Leidy.

Figure 1.—Skull seen from above. × $\frac{3}{4}$.
Figure 2.—Skull seen from below. × $\frac{3}{4}$.
Figure 3.—Skull seen from left side. × $\frac{3}{4}$.

Plate XIV.

Chrysemys wyomingensis (Leidy); carapace, showing supernumerary bones and scutes. × $\frac{3}{8}$. From photograph.

Plate XV.

Hadrianus majusculus Hay; shell seen from the left side. × $\frac{1}{4}$. From photograph.

Plate XVI.

Aspideretes beecheri Hay; skeleton seen from above. × $\frac{1}{4}$. From photograph.

BAËNA MARSHI Hay.

1

2

3

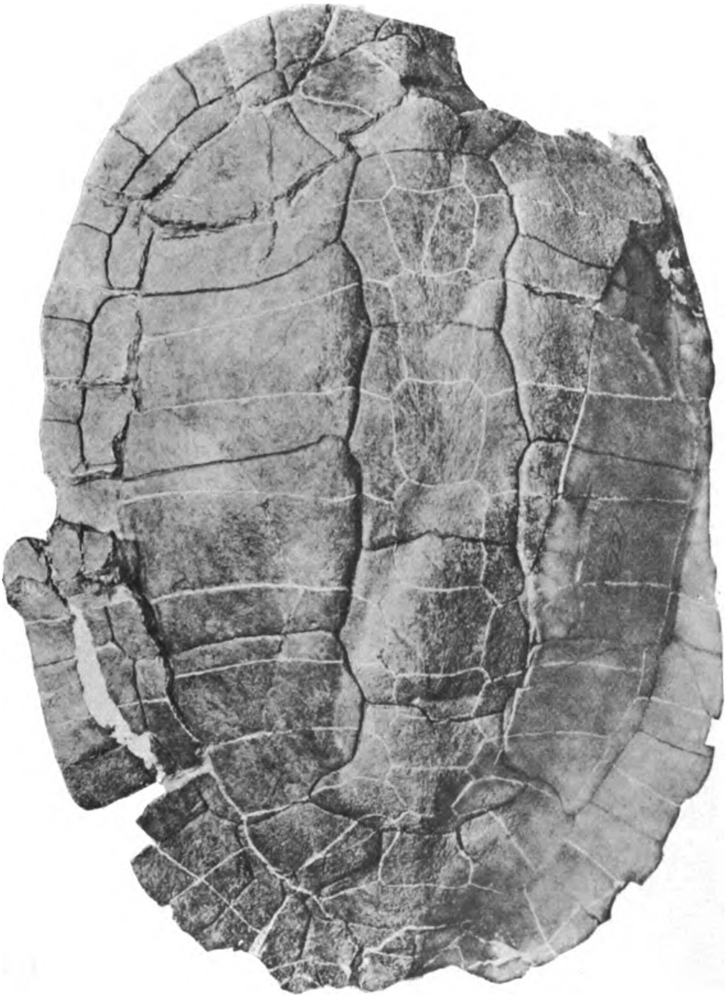
BAËNA CEPHALICA Hay.

1

2

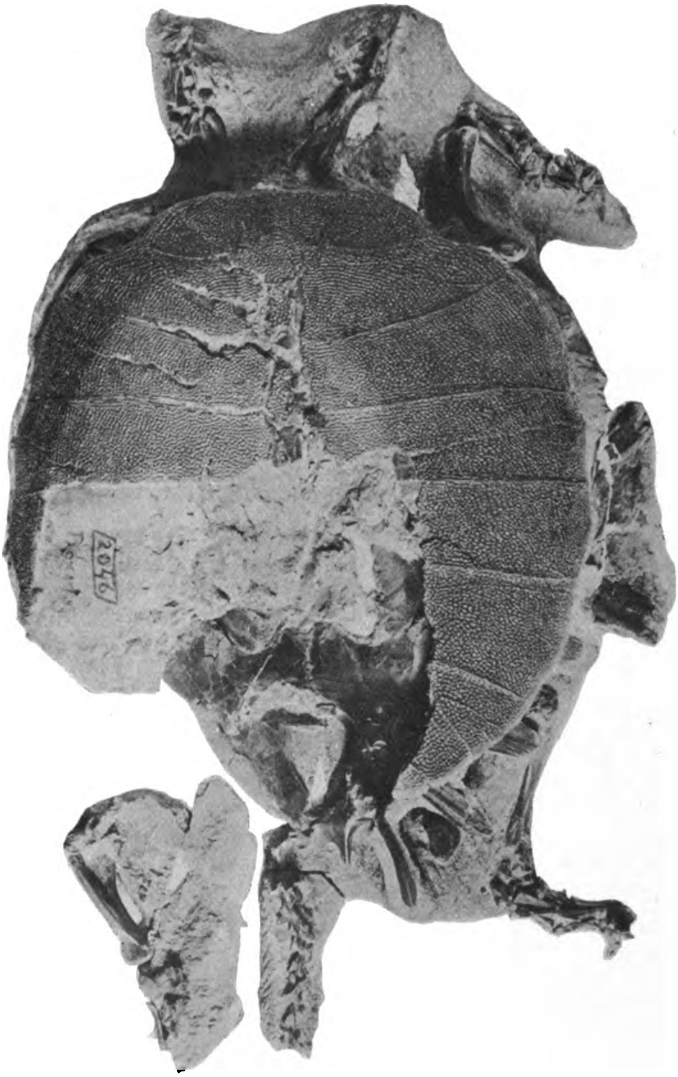
3

Baptemys wyomingensis Leidy.



Chrysemys wyomingensis (Leidy).

HADRIANUS MAJUSCULUS Hay.



Aspideretes beecheri Hay.

ART. XXXI.—*Air Radiation;* by C. C. HUTCHINS and J. C. PEARSON.

IN 1892, one of the present writers carried out, at the request of Professor Cleveland Abbe, some experiments for finding the radiation constant of atmospheric air. The radiation was measured from a hot moving column of air of one centimeter depth in the line of sight, and as close as possible, consistent with proper screening, to the heat-recording apparatus. Owing doubtless to defective surroundings, the results obtained from day to day showed considerable variation; in fact, more than could be produced artificially by changing the normal constituents of air in a closed room, such as dust and moisture, between wide limits. An average of the best results gave ·00000114 small calories per second per square centimeter per degree, for a thickness of 1^{cm} of the radiating layer.

In 1900, Professor Very published an extended monograph on the subject, in which very numerous experiments of his own and others are collected and discussed with the utmost skill and patience. Very's result, stated in the terms given above, at 100° excess temperature, was ·00000036, or three times smaller than what we had obtained. The large difference led to a reëxamination of our figures and methods without finding anything that could account for it. An entire change of apparatus and method often leads to unexpected results, and may cause us to modify our views as to the probable error of our former consistent figures. In 1902, we constructed an entirely new apparatus, containing nothing that belonged to the old. A radio-micrometer after Boys was the heat-receiving instrument. We avoided all suspicion of air contamination by taking air from out-of-doors. A box some 6 feet long, 2·5 feet wide, and 3 inches deep, containing a sheet-iron bottom about half-way up, and covered with a single sheet of glass, was set at an angle of about 45° outside a south window. The upper end of the box was extended by a wooden chimney that projected through a slit in the window shutter. The box had trunnions at the sides upon which it could be tilted by pulling a string. The radio-micrometer was mounted inside the shutter, so that in the lowest position of the chimney the current of air that streamed up through came opposite the radio-micrometer opening. Sunlight falling upon the exposed glass cover heated the sheet-iron bottom, and this in turn heated the air in contact with it, and a current of hot air was delivered through the chimney. The temperature of the hot air was obtained by a thermal junction of two thin copper and iron wires inserted in the stream, the circuit being completed through a calibrated galvanometer.

On clear, still days, excess temperatures of 50° to 60° of the hot air stream were obtained, and from the deflections produced as compared with those produced by a lampblacked surface at known temperature, we got values of the radiation constant that lay on both sides of the mean result of 1892. Great difficulty was experienced in getting a steady flow of hot air, and the behavior of the radio-micrometer was far from satisfactory. The experiments were discontinued when it was found that nothing new was to be learned by this method. We could at least conclude that the difference between pure air and that contained in an ordinary room with respect to radiating power was inappreciable.

The winter of 1902–3 was spent in improving the radio-micrometer, and an instrument of remarkable sensitiveness and accuracy was produced.*

This season we have taken up the problem anew with much improved apparatus and in very much improved surroundings. The investigation was carried out in the constant temperature room of the Searles Physical Laboratory, and the extreme range of temperature during the weeks of experiment has been less than 2°.

Finding our knowledge of the absorption of air for its own radiation in a very imperfect state, we turned our attention first to that problem.

Description of Apparatus.

The radio-micrometer was mounted upon a massive stone table, and screened from external sources of radiation. In line with the opening of the radio-micrometer was placed a truncated cone of sheet tin, 45^{cm} long, having an opening $1{\cdot}5^{cm}$ in diameter, corresponding to the opening of the instrument, and enlarging to $5{\cdot}5^{cm}$ at the other end. The cone is extended by a cold-drawn seamless brass tube, polished within, 280^{cm} long, and 5^{cm} internal diameter. Over the end of the brass tube is slipped a tin tube 8^{cm} in diameter, held in place by wooden rings and projecting 70^{cm} beyond the brass tube. These 70^{cm} are thickly set with diaphragms, having 5^{cm} openings, and the tube and diaphragms are carefully blackened. The legitimacy of using reflecting tubes for passing along a radiation from a distant source has often been called in question. All doubt should, however, be set at rest by recent experiments made upon the reflecting power of metals bathed in air, for long waves. Hagen and Rubens show† that all metals are practically perfect reflectors for radiations of great wave length, and it is certain that any difference between the reflecting power for air radiation, which is known to be of very great wave length, and the radiation from a lampblacked surface at slight

* This Journal, vol. xv, April, 1903. † Drude's Annalen, vol. ii, p. 873, 1903.

temperature excess, would be inoperative so far as our present purposes are concerned. Opposite the tin tube is placed the device for heating and delivering an air column. A box of wood 100^{cm} by 35^{cm} by 14^{cm} is mounted upon trunnions so as to be tilted by pulling an attached string. In its vertical position, the column of hot air is delivered centrally past the opening of the long tube, but upon releasing the string the box tilts back out of the way. Beyond the air column stands a large blackened copper cube filled with water at the room temperature, and to this all temperatures are referred.

The box is filled with coils of iron wire which are heated by a current taken from the lighting circuit, and the air flowing up through them is heated in turn. The temperature of the hot air is given by a thermometer having a very small bulb held in the stream at the height of the opening in the long tube.

Experiment to determine the Absorption in the Long Tube for Lampblack Radiation.

As our values of air radiation were to be obtained in terms of radiation from a lampblacked surface, it became necessary to inquire whether the column of air in the long tube exerts any appreciable absorption upon the lampblack radiation. Langley, in his work on the temperature of the moon, has shown that a column of air 110 meters deep absorbs about 20 per cent of the rays from a blackened surface at 100° C. If the absorption follows Lambert's law, it would, in a column of air 245^{cm} deep—the depth used in the following experiment—be about 0·5 of one per cent, and may be neglected. The object of the following was to ascertain if the absorption changes with temperature excess.

A second blackened tank at a higher temperature than the standard tank was thrust in front of the tube and the deflection of the radio-mircometer noted. The following table gives the results.

TABLE I.

Depth of absorbing column, 245^{cm}.

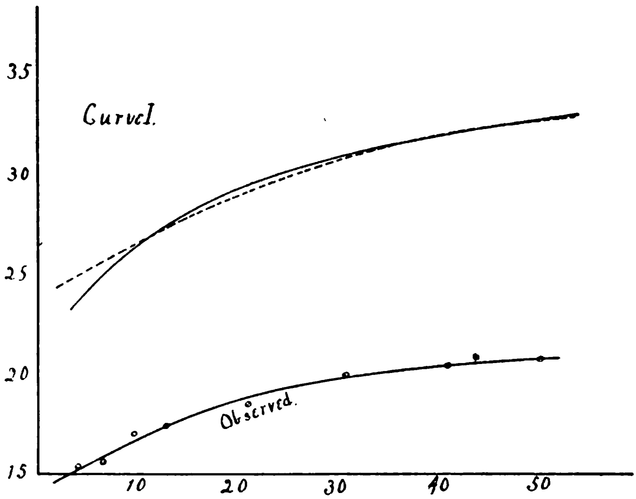
Excess Temp.	Mean Defl.
4°·06	62·6
6·62	103·5
9·55	163·0
12·79	224·0
12·18	51·63
20·91	94·17
30·60	145·3
40·90	200·3
50·00	252·5

The sensitiveness of the instrument was changed by withdrawing the condensing mirror at the point marked by the horizontal line through the table. To reduce all to a common scale, we need a reduction factor for change of sensitiveness. This will be the ratio of the deflection per degree excess for 12°·79 to the deflection per degree for 12°·18, assuming that the radiation rate is the same for these two near temperatures. After applying this factor and dividing each deflection by its corresponding temperature, we obtain the following:

TABLE II.

Excess Temp.	Defl. per Deg. Exc.
4°·06	15·42
6·62	15·63
9·55	17·07
12·79	17·51
20·91	18·61
30·60	20·01
40·90	20·23
50·00	20·86

M'Farlane gives a table* showing the radiation in small calories per second per square centimeter of a blackened surface. For 50° excess, M'Farlane's figure is ·000326. Multiply-



ing the number in the second column of Table II by such a factor as will reduce the last to ·000326, we plot a curve with excess temperatures as values of x, and the observed radiation rates, derived as above, as values of y, and along with it, a second curve from M'Farlane's observations.

* Proc. Roy. Soc, 1872, p. 93.

M'Farlane's curve is dotted. It will be seen that there is nothing shown by the above results from which increased absorption at small excess temperatures can be argued. Considering the widely different methods by which these curves were derived, their agreement is quite striking. We feel sure then that we shall commit no appreciable error in effecting a comparison of air and lampblack radiation if we assume that the latter is unabsorbed by columns of air of the depth used in our experiments. In fact, difference in the manner of preparation of the lampblack surfaces is known to cause greater radiation differences than are shown here.

Absorption of Air for its own Radiation.

The radiation of air cannot be properly considered apart from the question of the rate at which its own radiation is absorbed. Very* obtains a change of deflection per foot of increase in radiating depth of 8·3, 10·0, 8·2, 10·4, –1·2, the depths being 1, 2, 3, 4, and 5 feet, respectively. Disregarding the rather discordant character of these figures, he rejects the negative change for 5 feet entirely on what seems somewhat uncertain grounds. We have sought to avoid the difficulty of absorption in the radiating column itself by measuring the depth of the absorbing layer from the center of a radiating column only 10^{cm} deep; hence if there be any outstanding error, it must be very small and we believe negligible.

A complete example of the method of proceeding is here given. The long tube being in place and carefully covered with asbestos steampipe covering, the current was turned on in the heating box and at the end of half an hour the following deflections were obtained:

TABLE III.

	Defl.	
	55·	
	52·	Date, June 29
	54·5	
	53·	Air column, 491^{cm}
	55·5	
	55·5	Hot air temp. 142°
	52·	
	55·	Room temp. 20·5
	56·	
Mean	54·33	Hot air exc. 121·5

*Atmospheric Radiation, p. 45.

The warmed blackened tank gave the following deflections:

TABLE IV.

Temp. cold tank.	Temp. hot tank.	Deflections.
20·56	24·05	106·
	24·10	101·5
	24·18	109·5
	24·22	106·5
20·58	24·24	104·5
20·57	24·16	105·6

The mean deflection corresponding to 1° excess temperature of air is

$$\frac{54{\cdot}33}{121{\cdot}5}=0{\cdot}4472.$$

The excess temperature of the lampblacked surface is

$$24{\cdot}16-20{\cdot}57+0{\cdot}59=4{\cdot}18$$

where $+0{\cdot}59$ is the thermometer correction. Hence the deflection per degree excess for the lampblacked surface is

$$\frac{105{\cdot}6}{4{\cdot}18}=25{\cdot}26.$$

Finally, the ratio of the hot air radiation to that from the blackened surface is

$$\frac{{\cdot}4472}{25{\cdot}26}={\cdot}01770.$$

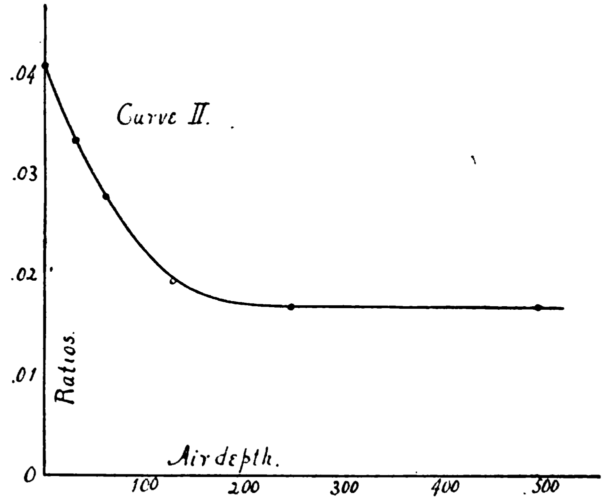
On July 1, we obtained ·159; on July 2, 0·177; on July 8, 0·1734; the average of six days being 0·1685.

The absorbing column was then made 245^{cm}, 127^{cm}, 61^{cm}, and 30^{cm}, and the same method followed for each distance, in each case the observations being distributed over several days. The results are tabulated below:

TABLE V.

Absorbing column	Mean Ratio
30^{cm}	·0332
61	·0278
127	·0195
245	·0169
491	·0168

Plotting these observations with the numbers in the first column of Table V as abscissas and the numbers in the second column as ordinates, we obtain the following curve:



An inspection of this curve reveals a very important feature of air radiation hitherto unknown; namely, that some 60 per cent of its own radiation is absorbed by a column as thin as 245^{cm}, the remaining 40 per cent being freely transmitted as though coming from a black body. We have plotted the ratios of air radiation to lampblack radiation per degree excess temperature. The point where the curve cuts the Y-axis will correspond to the ratio at zero depth of absorbing column, and is important to know. This point may be calculated as follows:

Let L=radiation from lampblack
b=radiation of air for which absorption is neglected
J'=Characteristic radiation from hot air, that is, b neglected
Then at zero depth, $b+J'$ is the total radiation from air. Lambert's law is $J=J'a^b$, and we have plotted the quantity $\frac{b+J'}{L}$ versus d. Taking $d_1=1$, and $d_2=2{\cdot}033$, we have

$$\frac{b+J_1}{L}=0{\cdot}0332=\frac{b+J'a}{L}, \tag{1}$$

$$\frac{b+J_2}{L}=0{\cdot}0278=\frac{b+J'a^{2.033}}{L} \tag{2}$$

$$\frac{b}{L}=0{\cdot}0169 \tag{3}$$

We wish to find the value of $(b+J')/L$.
From (3), $b=0{\cdot}169\ L$
whence, from (1), $J'a=0{\cdot}0163\ L$
and $a=0{\cdot}0163\ L/J'$

Substituting the values of a and b in (2), we get

$$0\cdot0109\ \mathrm{L} = \frac{(0\cdot0163\ \mathrm{L})^{2.033}}{(\mathrm{J}')^{1.033}}$$

whence $$\mathrm{J}' = \mathrm{L}\left[\frac{(0\cdot0163)^{2.033}}{0\cdot0109}\right]^{\frac{1}{1.033}}$$

This gives $$\frac{b + \mathrm{J}'}{\mathrm{L}} = 0\cdot0409.$$

This point fits in a perfectly satisfactory manner upon a smooth curve drawn through the observed points.

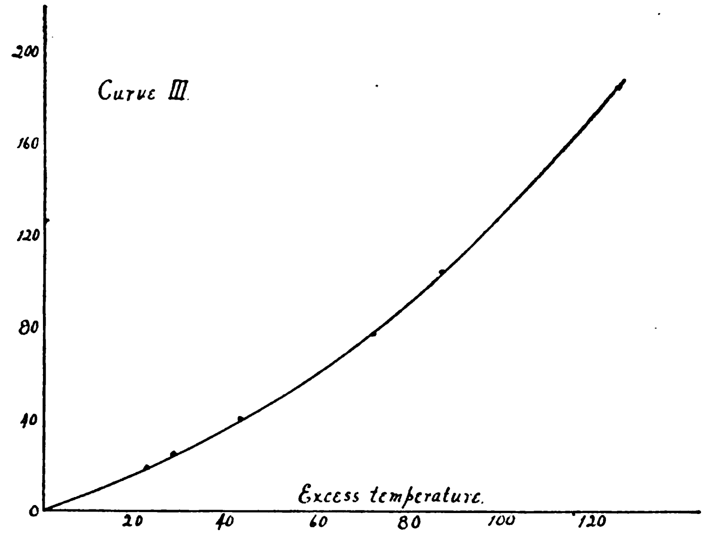
What the course of absorption may be beyond a depth of 500^{cm}, we have no means at present of judging. It may be suggested that the compound nature of air is responsible for its peculiar manner of absorption. Perhaps its contained water vapor is the substance radiating like a black body, and that apart from this, the strongly curved portion of our diagram shows the characteristic behavior of its prominent gaseous constituents. If this be true, it follows that the radiation of pure dry air is effective only at comparatively slight depths. The amount of moisture in the air during this course of experiments was considerable, the relative humidity not varying much from 78·2. It may be that water vapor so little removed from its point of saturation no longer behaves as a true gas, but as an aggregate of particles, in which case it would transmit all rays with considerable freedom, the particles producing a scattering effect merely. The accepted explanation of the color of the sky favors this view.

We have now to discuss the change of radiation of air with change of temperature. By introducing a variable resistance into the circuit of the heating box the temperature of the heated air could be changed at will. A mean of five to ten consistent observations was taken for each temperature and the results tabulated as follows:

TABLE VI.

Exc. Temp.	Mean Defl.
22°·5	18·55
28·2	24·9
43·2	40·9
72·1	77·9
87·0	105·7
125·5	185·9

Plotting deflections versus temperatures from Table VI, we obtain the following curve:



Calling D the deflection and t the temperature, the equation of this curve may be written,

$$D = At + Bt^2 + Ct^3$$

From which, using three observations, we obtain,

$$D = {\cdot}7185\ t + {\cdot}486\ t^2\ (10^{-2}) + {\cdot}96\ t^3\ (10^{-5})$$

the logarithmic coefficients being

$$\log A = 9{\cdot}856448 - 10$$
$$\log B = 7{\cdot}687127 - 10$$
$$\log C = 4{\cdot}984735 - 10$$

From the above the relative ratio of air radiation per degree at different temperatures may be found.

For $t = 1°$, we have $dD/dt = 0{\cdot}728$
For $t = 100°$, $dD/dt = 1{\cdot}98$

Hence the radiation per degree at 100° is $1{\cdot}98/0{\cdot}728 = 2{\cdot}72$ times greater than at 1°.

There remains before computing the value of the radiation constant to find the temperature gradient of the hot air column in the line of sight; laterally, the central portion of the air column only was used and no correction in that direction is required. A thermal junction of thin copper and iron wires was moved by steps through the heated air column, and the readings of a galvanometer, through which the junction was connected, noted. The edge of the opening in the air chimney being called 0, its center would be at 5. The following readings were obtained:

TABLE VII.

Dist.	Defl.
5·0	155
4·0	155
3·0	155
2·0	155
1·0	149
0·5	124
0·2	105
0·0	90
—0·2	75
—0·5	50
—1·0	22

The air flowing up past the outside of the warmed box gave the deflections for negative values of distance; the integral of these was nearly sufficient to balance the loss for less temperature within the range of positive values of the distance. By plotting a curve and integrating the positive and negative values with reference to distance, and radiation rate as derived from Curve III, we find the actual air column to be 0·967 as effective as a column 10^{cm} deep, and at a temperature measured at its center.

We are now prepared to calculate the radiation constant, h. Assume that this is wanted for an excess temperature of 100°, a depth of 1^{cm}, and zero absorbing column. We have:

Ave. of all exc. air temps. observed = 122°
Defl. for 122° from Curve III = 179
" " 100° " " " = 130
Rad. per deg. from lampbl. at 4° exc. (avg.) = ·000249 (M'Farl.)
Ratio of air to lampblack radiation for zero absorbing column, from Curve II, = ·041

Therefore $h = (130/179)\,(\cdot 000249)\,(0\cdot 1)\,(\cdot 041)\,(0\cdot 967)$
$= 0\cdot 000000717$ water-gram-degrees per sq. cm. per sec. per deg. exc. temp.

For 1°, this becomes 0·000000264, and may be found with great facility from the curves given, or from their equations, for any temperature or depth of absorbing column within the limits of our observations.

If our surmise be correct that the freely transmitted part of moist air radiation is from its contained water vapor, amounting to 40 per cent of the whole, then the above numbers would become for dry air, 0·00000043 and 0·00000016, respectively.

Bowdoin College, July, 1904.

ART. XXXII.—*Uintacrinus and Hemiaster in the Vancouver Cretaceous;* by J. F. WHITEAVES.

VERY few remains of echinodermata have hitherto been found in the Cretaceous rocks of Vancouver and the adjacent islands. Those enumerated in the latest and most complete list of the fossils of these rocks, published by the Geological Survey of Canada in 1902, are only fragments of the test of a regular echinid; portions of the ray of a five-rayed starfish; a five-lobed joint of the column of a pentacrinite; and a fragment of the basal portion of the dorsal cup of a crinoid. Although three of the classes of echinodermata were then known to be represented in these rocks, it was by such fragmentary specimens that it was scarcely possible to determine them, even generically.

But, in a collection of Cretaceous fossils from various localities on or near Vancouver Island, recently sent to the Museum of the Canadian Geological Survey by Mr. Walter Harvey, there are two fairly good specimens of a crinoid, and as many as forty of a spatangoid or heart urchin.

The two crinoids evidently belong to the same species, and are obviously referable to the sessile genus *Uintacrinus*, Grinnell.

One of them is a comparatively large cast of the interior of a dorsal cup, crushed nearly flat, upon a piece of brittle shale from the north bank of the Cowichan River, V. I., about a mile above the bridges at Duncan's, collected by Mr. Harvey in 1903. It is well preserved and shows a monocyclic base, with an undivided centrale, five small basals, five large radials; the third circlet of plates, and a few plates of the fourth. In their shape and arrangement, the whole of these plates correspond very well with those of some regular, monocyclic specimens of the dorsal cup of *Uintacrinus*, as figured in the latest memoir on that genus by the Hon. Frank Springer (1901) and as shown in some fine specimens of *U. socialis* from Kansas, kindly forwarded by Mr. Springer for comparison.

The other specimen is a small, badly preserved and rather worn cast of the interior of a calyx, also crushed nearly flat, from similar shales about a mile south from Vesuvius Bay, Salt Spring Island, in the Strait of Georgia, collected by Mr. Harvey in 1902.

Both of these specimens are clearly referable to the genus *Uintacrinus*, but they are scarcely sufficiently perfect for specific determination or description, though it must be admitted that they show no characters by which they can be

satisfactorily distinguished from some forms of the typical and very variable *U. socialis.*

In Utah and Kansas *Uintacrinus* is said to have been found only in the Niobrara chalk, but the exact equivalent of that subdivision of the Upper Missouri section has not yet been recognized in the Nanaimo group of the Vancouver Cretaceous. The specimens of *Uintacrinus* from Vancouver and Salt Spring islands are from the lower beds of the Nanaimo group, below the coal, and it has yet to be ascertained whether the genus occurs at a little higher geological horizon than the Niobrara at those islands, or whether the supposed lower beds of the Nanaimo group may not at some places represent or include the Niobrara. In the Queen Charlotte Islands the "Upper shales and sandstones, or subdivision A, of Dr. G. M. Dawson's Report" on these islands, which hold *Inoceramus labiatus (problematicus)* are supposed to represent the Niobrara.

The spatangoids are casts of the interior of the test of a species of *Hemiaster*, from shales and sandstones of the Nanaimo group, at four localities on Vancouver Island and one on Salt Spring Island. Many of these casts are distorted and crushed out of shape, but others are well preserved and very little if at all distorted. Two of them, in particular, are almost perfect and very well preserved, and both of these have recently been presented to the Museum of the Canadian Geological Survey. One of them, the first that was obtained, was found by Miss Wilson, in 1897, on the north bank of the Cowichan River, V. I., near Menzies Creek; and the other by Mr. Harvey, in 1903, at Shopland, V. I. Mr. Harvey writes that he has found specimens of this heart urchin all over the Cowichan coal-field, V. I., at the northeast end of Salt Spring Island, and at Crofton, V. I., the most southerly point of the Nanaimo coal-field, in 1902, 1903 and 1904.

Only one species of *Hemiaster* has previously been recorded as occurring in the Cretaceous rocks of North America. This is the *H. Humphreysanus*, from the Fort Pierre or Montana formation of the Upper Missouri country, and district of Athabaska, which was first described by Meek and Hayden in 1857, and re-described and figured by Meek in 1876. But the fauna of the Cretaceous rocks of the Pacific coast is in many respects different to that of their representatives in the great interior plateau, and the Vancouver *Hemiaster* seems to differ from *H. Humphreysanus* in its much more depressed and widely suboval or subovate form. It may be provisionally named and described as follows:

Hemiaster Vancouverensis, sp. nov.

Cast of the interior of the test widely suboval or subovate in marginal outline, a little longer than wide, and widest at or a little in advance of the midlength, with the posterior end abruptly and almost vertically truncated in some specimens but not so much so in others. Dorsal or abactinal surface depressed convex, very slightly elevated, most prominent at a short distance from the posterior end; ventral or actinal surface flattened; greatest height about one-half of the maximum length. Oral aperture not well shown in any of the specimens collected, vent small, a little higher than wide, placed high up on the truncated posterior extremity and near the abactinal surface; apical disc situated at a considerable distance behind the midlength in some specimens, but not very far from median in others. Ambulacra very unequal in length; the odd anterior ambulacrum being a little longer than the anterolaterals, but rather indistinctly defined at the anterior end, and the anterolaterals much longer than the short posterolaterals. Anterior median sulcus shallow but well marked, and giving a faintly emarginate or subemarginate outline to the anterior end. Anterior ambulacrum entirely included within the median sulcus; anterolateral ambulacra petaloidal, narrowly elliptical and shallowly depressed; posterolateral ambulacra also shallowly depressed, somewhat similar in shape to the anterolaterals, but not more than one-half of their length. Spines and exterior of the test unknown.

The foregoing description is based almost exclusively upon the two nearly perfect and undistorted casts from the Cowichan River and Shopland, already referred to, and these may therefore be regarded as the types of the species.

Ottawa, August 28, 1904.

Art. XXXIII.—*The Separation of the most Volatile Gases from the Air without Liquefaction;** by Sir James Dewar.

[Read before the Royal Society of London, June 16, 1904.]

From the time when liquid air came to be an ordinary laboratory agent I have continually used it for the purpose of producing high vacua in vessels that had been previously filled with easily condensable gases, like sulphurous acid, carbonic acid, vapor of water or benzol.

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When the liquefaction of hydrogen was effected, one of the first scientific uses to which it was put was that described in my paper on the "Application of Liquid Hydrogen to the Production of High Vacua, together with their Spectroscopic Examination."† In that communication it was shown by theory and confirmed by experiment that the condensing power of liquid hydrogen is so great relatively to that of liquid oxygen or nitrogen, that any closed vessel, a part of which is cooled to the boiling point of hydrogen, must suddenly become a highly vacuous space. This was proved by the great difficulty of getting electric discharges to pass through specially prepared spectroscopic tubes when subjected to liquid hydrogen cooling, and from the fact that when the current did pass no lines of oxygen or nitrogen were seen, but only those of hydrogen, helium and neon. In order to separate these latter gases from air it was necessary to liquefy a quantity of air and to distill off the most volatile portion at as low a temperature as possible into a separate receiver placed in liquid hydrogen. In this way many spectroscopic tubes were filled with the uncondensable air gases and the results of their examination is recorded in a paper entitled "On the Spectra of the more Volatile Gases of Atmospheric Air, which are not condensed at the Temperature of Liquid Hydrogen,"‡ by Professor Liveing and myself. Some two years later I improved the method of separation of the volatile air gases. The process is fully described and illustrated in my paper on "Problems of the Atmosphere."§ Its success depends upon the continuous direct liquefaction of air at atmospheric pressure combined with a device which

* From an advance proof sent by the author.
† Proc. Roy. Soc., vol. lxiv, 1898.
‡ Proc. Roy. Soc., vol. lxvii, 1900.
§ Proc. Roy. Inst., 1902.

enables the more volatile gases to be trapped and separated. In this way some 1/35,000th of the volume of the air liquefied is collected as a gaseous mixture, having the composition 38 per cent of nitrogen, 4 per cent of hydrogen, and 58 per cent of mixed helium and neon. After sparking to remove the nitrogen and hydrogen a gaseous mixture of helium and neon containing a little argon was obtained. This mixture had the composition of 16 per cent helium and 84 per cent neon. In both methods of treatment it will be noted the liquefaction of the air was the essential preliminary operation, to be supplemented in the one case by the use of liquid hydrogen, in the other by sparking to remove the nitrogen. The paper already communicated to the Royal Society,* entitled "The Absorption and Thermal Evolution of Gases Occluded in Charcoal at Low Temperatures," in which the greatly increased power of occlusion possessed by charcoal at low temperatures is proved, suggested an inquiry into the limits of gaseous pressure reached by such means of condensation.

With this object a narrow tube CE, fig. 1, was sealed to an ordinary spectroscopic sparking tube AB, and at the end E an enlarged space was blown out capable of holding a few grams of cocoanut charcoal. After the charcoal had been freed from gases by heating and exhaustion and the poles cleared by sparking during this operation, pure and dry gases like oxygen, nitrogen, air, carbonic oxide, hydrogen, neon and helium could be admitted at different pressures and the tube with its charcoal chamber attached sealed off.

On placing the charcoal end of the apparatus in liquid air, the gas in each case was rapidly absorbed and the vacuum produced reached the phosphorescent stage in all cases with the exception of hydrogen, neon, and helium. A small Crookes' radiometer, full of air at atmospheric pressure, with charcoal tube attached, became quite active to heat radiation when the charcoal was cooled for half a minute in liquid air. To test the amount of exhaustion reached by the use of a given weight of cocoanut charcoal, I sealed on a tube containing 30 grams to a large electric discharge tube of 1300 c.c. capacity filled with air at atmospheric pressure. On cooling the charcoal receptacle in liquid air the pressure diminished to 50^{mm} of mercury. Repeating the same experiment but starting with the tube initially at half an atmosphere, the exhaustion reached was now beyond the striæ stage. A further experiment starting with one-fourth of an atmosphere gave a vacuum through which no discharge passed.

Finally, the 30 grams of charcoal were replaced by only 1 gram and the initial pressure was reduced to 3^{mm} of mercury.

* This Journal, p. 295 following.

Now the vacuum just reached the beginning of the phosphorescent stage. With hydrogen, either a pressure of gas less than that of the atmosphere had to be used at starting or a larger amount of charcoal employed in order to get a vacuum well up in the striæ stage. If, however, the liquid air was cooled to −210° C. by exhaustion, the tube just reached the beginning of phosphorescence round the cathodes.

With helium there was a very slight absorption, but neon did show something more appreciably. Spectroscopic observations made during the condensation of the gas in the charcoal showed the gradual disappearance of the characteristic spectrum of oxygen, nitrogen and air, as the high vacuum was reached and the discharge passed with great difficulty. In

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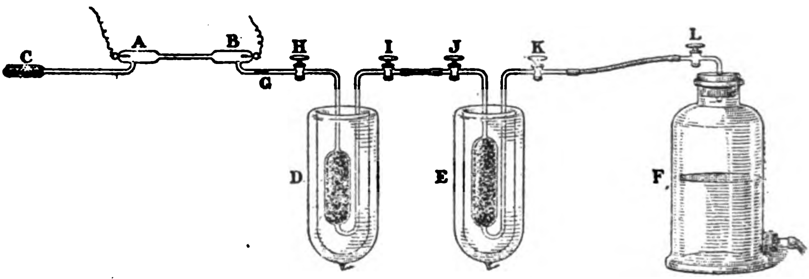

tubes of this kind filled at atmospheric pressure I could always see the F line of hydrogen and the neon yellow; but the helium was not seen with any definiteness. As the amount of neon in the air cannot well exceed 1/50,000th the spectroscopic test is very delicate.

In order to bring in the helium lines it was necessary to concentrate the volume of air in the space of the sparking tube six or seven times. This was done by the use of an arrangement shown in fig. 2. AB is the sparking tube with its small charcoal bulb C attached, capable of being sealed off when required at G; and D and E are larger charcoal absorbers placed in vacuum tubes containing liquid air; the whole being attached to a graduated gas-holder containing air. A series of glass stop-cocks are attached at the points H, I, J and K in order to facilitate manipulation. In determining the volume of air required to bring in the helium lines, only one charcoal absorber containing about 15 grams of material was used. On allowing 200 c.c. of air from the gas holder to be sucked into the charcoal (which had been previously exhausted along with the sparking tube) on opening the stop-cock H any residuary

gas in D was swept into the sparking tube, which was then sealed off at G.

This tube gave the hydrogen lines C and F, the neon yellow, and some of the orange lines, along with the helium yellow and green quite distinct. With the residuary gas extracted from one liter of air I could see all the helium lines. On the positive pole the neon yellow and the green of helium were alone marked, while the negative pole gave both the neon and helium yellow lines along with the helium green and the F of hydrogen on the continuous spectrum. From this it would appear that the spectroscopic test for helium is as delicate as that for neon, and that 1/50,000 can be recognized. From 3 liters of air discharge tubes were obtained, giving the neon and helium spectra associated with a brilliant ruddy glow discharge.

As 40–50 grams of charcoal can absorb at the temperature of liquid air from 5–6 liters, it is easy to accumulate rapidly the uncondensed gases in considerable quantities for spectroscopic examination. For this purpose I found it convenient to use two charcoal condensers in circuit as represented in fig. 2. After the charcoal in the first one marked E was saturated, the stop-cock K was closed, while I and J were opened for a short time so as to allow the less condensable gas in E to be sucked into the second vessel of the same type D along with some portion of air. The charcoal condenser E was then taken out of the liquid air, and rapidly heated to 15° C. in order to expel the occluded air. It was thus in a condition to repeat the absorption. In this way 50 liters of air can be treated in a short time. Sparking tubes filled from the accumulated gases in D were very brilliant, showing the complete spectrum of the volatile constituents of air. It is hardly necessary to remark that after the little charcoal receptacle connected to each of the sparking tubes has been cooled and thus all traces of air absorbed, it can be sealed off, leaving the spectroscopic tubes intact. The complete spectroscopic study of the products must be left for further examination with Professor Liveing.

The method I have described will be equally applicable to the treatment of the gaseous products from minerals containing helium, hydrogen, etc., and also to the radium products of a similar kind. It seems even probable that the separation of the less volatile constituents in air may be improved by a slight modification in the mode of working. The behavior of the gases from the Bath Springs has been examined. When the gas containing 1/1000th part of helium in what may be regarded as pure nitrogen is subjected to charcoal absorption exactly in the same way as the air was treated, no high vacuum

is reached. All the nitrogen and any other constituents disappear, and a spectrum of helium and hydrogen, showing much less neon than exists in the volatile residue from atmospheric air, is the result. A sample of argon made from Bath gas gave, when the argon was absorbed in charcoal, a gas residuum giving the helium and neon spectrum, and the same result follows the use of atmospheric argon. In the case, however, of the Bath gas argon the helium spectrum is the stronger, whereas with air argon the neon is the most pronounced.

In order to further test the method, the crude gases got by heating the mineral fergusonite were examined. During the cooling of the charcoal the nitrogen and hydrogen spectra were marked, but in a short time nothing could be seen but the lines of hydrogen and helium.

Great interest will attach to the behavior of helium, hydrogen and the most volatile part of air, when subjected to the action of charcoal cooled to the temperature of liquid hydrogen. The method promises to open up many avenues for future inquiry.

ART. XXXIV.—*The Absorption and Thermal Evolution of Gases occluded in Charcoal at Low Temperatures;* by Sir JAMES DEWAR.*

[Read before the Royal Society of London, June 16, 1904.]

DURING the year 1874–5, in association with the late Professor Tait, a research was undertaken which involved the production of very perfect vacua, and with the object of improving on the then known methods, dense charcoal was employed as an efficient absorbent of traces of any gaseous residuum. An account of these experiments communicated to the Royal Society of Edinburgh appeared in Nature, July 15, 1875, under the title of "Charcoal Vacua."

In Professor Clerk Maxwell's Notes on "Molecular Physics" the following succinct description of the process is given: "Another method employed by Professor Dewar is to place in a compartment of the vessel a piece of freshly heated cocoanut charcoal, and to heat it strongly during the last stages of the exhaustion by the mercury pump. The vessel is then sealed up, and as the charcoal cools it absorbs a very large proportion of the gases remaining in the vessel.

"The interior of the vessel, after exhaustion, is found to be possessed of very remarkable properties. One of these properties furnishes a convenient test of the completeness of the exhaustion. The vessel is provided with two metallic electrodes, the ends of which within the vessel are within a quarter of an inch of each other. When the vessel contains air at the ordinary pressure a considerable electromotive force is required to produce an electric discharge across this interval. As the exhaustion proceeds, the resistance to the discharge diminishes till the pressure is reduced to that of about a millimeter of mercury. When, however, the exhaustion is made very perfect the discharge cannot be made to take place between the electrodes within the vessel, and the spark actually passes through several inches of air outside the vessel before it will leap the small interval in the empty vessel. A vacuum, therefore, is a stronger insulator of electricity than any other medium."

At one of the conferences held in connection with the Special Loan Collection of Scientific Apparatus† in the year 1876, I showed that with a vapor like bromine the absorptive power of the charcoal was so effective that a space filled with

* From an advance proof-sheet by the author.

† See Science Conferences, Physics and Mechanics, p. 154.

the vapor even at atmospheric pressure could be made into a fairly high vacuum showing very wide striæ. When the charcoal was heated the bromine vapor was again expelled, and on allowing it to cool, all stages in the appearance of the electric discharge as the vacuum is reached could be conveniently observed without the use of any form of air-pump.

When in the course of low temperature investigations the perfection of the vacuum vessels for the storage and manipulation of liquid air and hydrogen came to be important, the effect of charcoal on heat isolation in such utensils was fully

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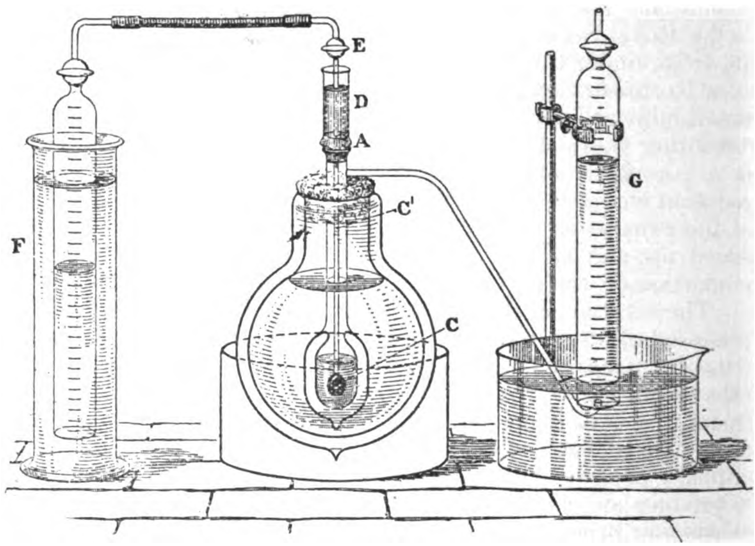


investigated and confirmed in a paper entitled "Liquid Air as an Analytic Agent."* Still no systematic experiments on the absorptive power of charcoal at low temperatures were made either at this time or subsequently.

It is the object of the present preliminary paper to contribute some definite quantitative data regarding gas absorption and thermal evolution in charcoal at the temperature of liquid air. The mode in which liquid gases like oxygen or air could be used as calorimetric agents was described in my paper on the "Scientific Uses of Liquid Air."†

* Proc. Roy. Inst., 1898.
† Proc. Roy. Inst., 1894.

The apparatus was further improved into the form illustrated and described in Madame Curie's Work, "Recherches sur les Substances Radio-Actives," 2d edition, p. 100, as used for the determination of the heat evolved by radium bromide either in liquid oxygen or hydrogen. Such calorimeters are easily adapted to the simultaneous observation of the volume of any gas absorbed by charcoal, and of the concomitant heat evolution.

For this purpose a small glass bulb C (fig. 1) containing from 0·5–1 gram of charcoal has a long narrow tube C' attached, so that it can be immersed in the liquid oxygen or air in the calorimeter A B, while still allowing a part of the tube to project above the cork A. In order to dry and cool the 40 c.c. of gas, which represents the largest volume taken in by the charcoal in my experimenfs, a little annular space is arranged at D into which liquid air is poured immediately before the experiment is made.

The charcoal, after being placed in the tube C, is heated to a low red heat and simultaneously exhausted by a good air-pump, and after all the gas has been removed the stop-cock E is closed. In this condition it is placed in the calorimeter.

The experiment is conducted by connecting the end of the tube at E by means of an india-rubber tube with a graduated vessel F containing the gas. When all is ready the stop-cock E is opened, so that the gas may rush into the charcoal, and the heat evolved by its absorption distills off the equivalent quantity of liquid air from the calorimeter, which is measured in the vessel G.

The constant of the calorimeter being known (which with liquid air is about 14·5 c.c. per calory), we get the actual thermal evolution together with the volume of gas absorbed.

The heat correction for the rush of gas into the same exhausted glass bulb without charcoal is small in proportion to the total heat evolved, and the same may be said of the volume correction on account of the cooling of the space external to the charcoal. With a variable material like cocoa-nut charcoal I have in the calorimetric experiments used the same sample in all cases. The following table embodies the general results per cubic centimeter of charcoal. The gas absorption is given at 0° and 760^{mm}. If the volume of gas absorbed had been measured under the same conditions of pressure at −185° C., then the numbers in Column II would all have to be divided by three.

	I. Volume absorbed. 0° C.	II. Volume absorbed. −185° C.	III. Heat evolved. Gram-calories.
Hydrogen	4 c.c.	135 c.c.	9·3
Nitrogen	15 "	155 "	25·5
Oxygen	18 "	230 "	34·0
Argon	12 "	175 "	25·0
Helium	2 "	15 "	2·0
Electrolytic gas	12 "	150 "	17·0
Carbonic oxide and oxygen	30 "	195 "	34·5
Carbonic oxide	21 "	190 "	27·5

In all cases, it will be observed, the amount of gas occluded has been greatly increased at the low temperature, and the degree of condensation is generally such as we should anticipate from the known physical constants of the gases. The amount of heat evolved is so great as to be in excess of that required for liquefaction in the case of gases like hydrogen, nitrogen, and oxygen. The heat produced when successive fractions of the volume of gas required for saturation are absorbed has yet to be determined. In the time required for the absorption no measureable amount of chemical combination was effected between mixtures of hydrogen and oxygen or carbonic oxide and oxygen in the pores of the charcoal.

Such experiments must be extended to the use of platinized charcoal and other catalytic agents.

Perhaps the most striking result is the great difference in properties exhibited by helium. While resembling the other gases in showing increased absorption at the temperature of liquid air, the absolute amount occluded per unit volume of charcoal is about one-tenth that of the other gases at the same temperature. There can be little doubt that when the relative absorption of helium in charcoal is measured at the temperature of liquid hydrogen, the increased absorption will be so marked as to make it comparable to that of hydrogen in the present set of experiments. In this case charcoal at the boiling point of hydrogen will become an efficient condensing agent for helium, and this property will have important applications in future research.

Separation of Highly Concentrated Oxygen from Air.

In order to examine the changes taking place in a mixed gas like air during the absorption, a quantity of about 50 grams of charcoal was, after heating and exhaustion, saturated at −185° in a current of pure dry air; got by passing the air current through a U-tube immersed in liquid air.

For a time the air rushed into the charcoal with great rapidity, and in about 10 minutes between 5 and 6 liters were taken in.

A manometer attached to the vessel containing the charcoal showed, on shutting off the air current, that during the early part of the saturation the absorption was so effective as to give practically no measurable mercury pressure. As soon as the absorption was ended, and a current began to pass slowly over the charcoal, the composition of the air leaving the charcoal showed 98 per cent nitrogen. After the current of air had passed for half an hour, the total gas occluded in the charcoal was expelled by taking the vessel in which it had been treated out of the liquid air, and allowing the temperature to rise to 15° C.

The gas, which was rapidly expelled, measured 5·7 liters, and contained 56 per cent of oxygen. If the saturated charcoal before heating up was subjected for an hour to the action of an air-pump, capable of giving a steady exhaustion of 5^{mm}, no difference was effected in the oxygen percentage of the evolved gas. The same experiment was repeated with this variation, that, instead of the air current having the pressure of the atmosphere, it was kept below one-tenth of an atmosphere. In this experiment, 4·8 liters were expelled on heating up, and the percentage of oxygen was 58. Then a further repetition was made with an air current supplied at a pressure not exceeding 5^{mm} of mercury. After 3 hours' treatment, the charcoal, on heating to 15° C., gave 4½ liters of 57 per cent oxygen. From these experiments it follows that the tension of the occluded gases, at the temperature of liquid air, must be very small, and thus the use of low temperatures, combined with charcoal, introduces a new and greatly improved means of getting high vacua, which in the future may be found susceptible of important practical applications. These experiments are quite conclusive as to the practical constancy of the mean composition of the air gases occluded in the charcoal (subject to the conditions aforesaid), and they further show that wide changes in the pressure of the air current has little or no effect in altering the proportions. In another experiment, the vessel containing the saturated charcoal, instead of being allowed to rise rapidly in temperature, was transferred to a vacuum vessel, in which a little liquid air was placed, in order that the temperature might rise slowly, and thereby enable the successive liters of gas given off to be collected separately and analyzed.

This experiment gave the following results:—

	Oxygen per cent.
First liter	18·5
Second "	30·6
Third "	53·0
Fourth "	72·0
Fifth "	79·0
Sixth "	84·0

The mean composition of the 6 liters is again 56 per cent oxygen. From the above experiments it follows that one of the most rapid means of extracting a high percentage of oxygen from atmospheric air is to absorb it in charcoal at low temperatures, and then to expel it either rapidly or slowly by heating the mass of charcoal to the ordinary temperature.

A few experiments have been made using, instead of air, special mixtures of oxygen and nitrogen. Thus it was found that a gas containing 6·5 per cent of oxygen used in the same manner as in the air occlusion experiments, gave, on heating up the charcoal rapidly to 15° C., 5 liters of gas having the composition of 23 per cent. of oxygen. A repetition of the same process with the 23 per cent of oxygen would have raised the percentage about 60 per cent, or a stronger concentration could have been reached by fractionating the gas as it slowly leaves the charcoal on gradually increasing the temperature.

This preliminary investigation suggests many fields for furture inquiry, and some of these I hope to deal with in future papers.

ART. XXXV.—*Studies in the Cyperaceæ;* by THEO. HOLM. XXIII. The Inflorescence of Cyperus in North America. (With figures in the text.)

A GENERAL consideration of the structure of the inflorescence in *Cyperus* must necessarily result in the conclusion, that throughout the genus the structure is most essentially the same. The components are invariably the same: the involucral leaves, the prophylla, the branches, the floral bracts and the flowers, all these are clearly represented in each species; nevertheless some differences in aspect are frequently quite obvious, but depend to a very large extent simply upon mere variations in the length of the inflorescential branches, in the position of the spikes, their external shape and the manifold structure of the small, floral bracts.—Some of these characters, however, are often deceptive; because in the same species, it is not unusual to meet with individuals in which the number of spikes is reduced to one or two, nearly sessile, with the involucral leaves and prophylla very inconspicuous, while typically developed specimens may possess an ample inflorescence with long leaves and tubular prophylla.

The division of the genus in sections: *Pycreus*, *Cyperus* proper, *Papyrus*, *Diclidium* and *Mariscus*, is not directly based upon deviation in respect to the real components of the inflorescence, but only in regard to the structure of the spikes and the flowers, especially the arrangement and direction of the spikes, the shape of the rhachis and the structure of the achenes. The specific distinction is not materially dependent upon the main inflorescence, inasmuch as the same form is to be observed in remote sections of the genus, but here our attention is directed to the color and minor structure of the spikes, which constitute the ultimate divisions of the inflorescence, also, in some cases, to the structure of the rhizome.

In presenting a brief description of the inflorescence of the genus, we freely admit that we have nothing to add to the old, but most excellent one, given by Fenzl in his paper on *Cyperus Jaquini* Schrad,* or to the more recent one by Clarke,† but we wish to bring out a few points relating to the structure and function of the fore-leaves, which deserve some attention and which ought not to be passed by entirely in systematic treatments of the genus, as has been the case in American literature. It is, furthermore, the writer's desire to demonstrate, that some of the foliar organs which are pres-

* Denkschr. Math.-Naturw. Cl. Akad. d. Wiss., Wien, vol. 8, 1855.
† Journ. Linn. Soc., vol. 21.

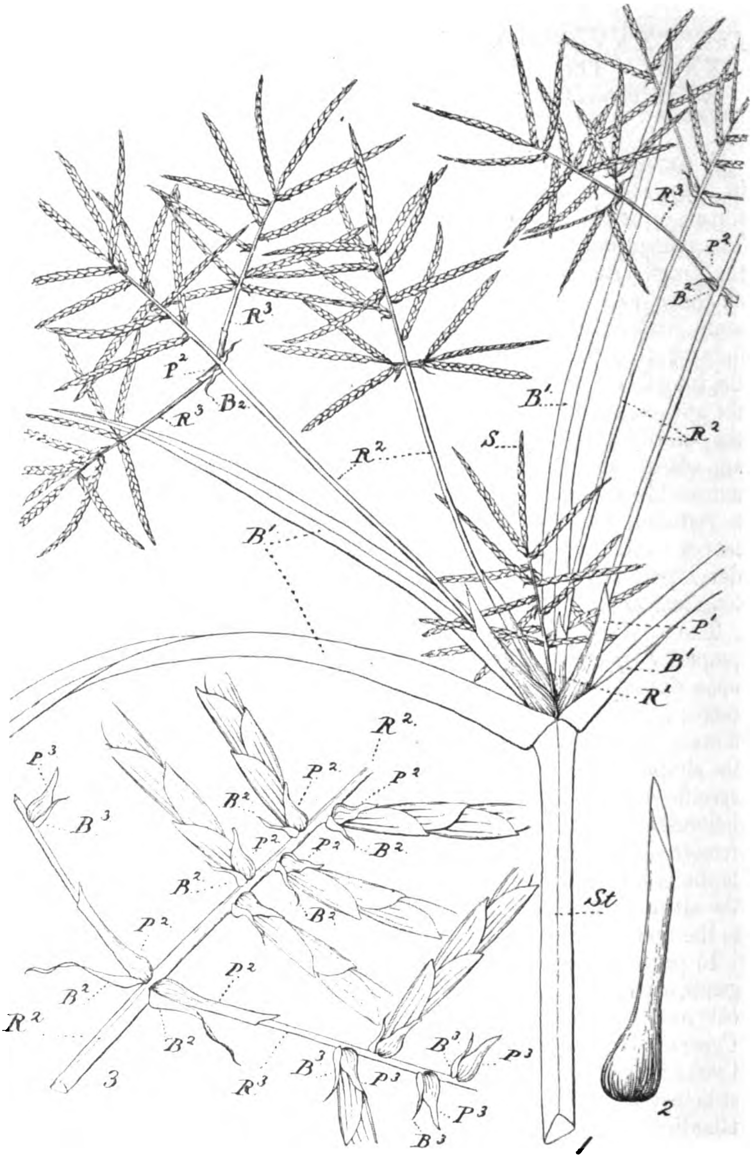


FIGURE 1. Inflorescence of *Cyperus phymatodes*, natural size.

FIGURE 2. A prophyllon from the base of a secondary ray of same magnified.

FIGURE 3. Part of the inflorescence of same, magnified. The letters are explained in the text.

ent in the inflorescence of *Cyperus*, are, to some extent, also observable in the panicle of certain *Gramineæ*.

Among the species of *Cyperus*, in which the inflorescence is ample and in which all the foliar organs are well developed and easily distinguishable, *C. phymatodes* Muehl. may be used for illustrating the composition. The accompanying figure 1 represents the upper part of the flower-bearing stem (St.) with the long, leafy bracts (B^1) arranged in a whorl near the apex and supporting secondary branches or rays, as they are often called (R^2), each of which bears a tubular prophyllon or fore-leaf (P^1) at the base.

The flower-bearing stem itself is terminated by a spike (S), borne on a similar ray (R^1) with several lateral spikes besides, but of course destitute of any bract or fore-leaf, since it is terminal. Each of the axillary rays (R^2) bears one pair of nearly opposite rays (R^3), subtended by very small bracts (B^2) and provided with minute fore-leaves (P^2); above these secondary rays (R^3) there is a number of sessile spikes, of which the uppermost is the terminal. By examining these sessile spikes, magnified in our figure 3, it is readily seen that with the exception of the terminal, they are subtended by small bracts (B^2) and that each spike bears a fore-leaf (P^2); moreover this same manner of ramification becomes repeated in the minor inflorescence of third order where the branch (R^3) with its bract (B^2) and fore-leaf (P^2) bears some spikes of third order each with a small bract (B^3) and a fore-leaf (P^3) at the base.—The flower-bearing stem (St. in fig. 1.) is, thus, extended into a short and slender rhachis (R^1) above the involucral leaves (B^1) and this rhachis or ray (R^1) is terminated by a sessile spike (S), overtopping a various number of scattered, sessile and simple spikes, all of which are lateral, being developed from the axils of small bracts. and each bearing a minute fore-leaf at the base. The only difference between this terminal inflorescence (R^1—S) and the larger, lateral ones depends, thus, merely upon these being supported by bracts (B^1) and by the presence of fore-leaves (P^1); these fore-leaves (fig. 2.) correspond to the so-called cladoprophylla, which we have described in a paper upon *Carex*.*

This type of umbellate inflorescence is characteristic of several other genera within the order, and is well represented in certain species of *Scirpus*, *Eriophorum*, *Fimbristylis*, etc. It is, moreover, to be found in *Dulichium*, but with the difference that in this genus the inflorescence, although composed of exactly the same organs, is very long, the internodes between the leaves, which subtend the lateral rays, being developed as distinct internodes, and the subtending leaves being provided

* This Journal, vol. ii, p. 214, 1896.

with long sheaths in contrast to the umbellate inflorescence in *Cyperus* with sheathless, involucral leaves. Otherwise we find in *Dulichium*, as already described, the same fore-leaves though weakly developed, since they are hidden in the sheaths of the bracts, and have not the same function as those in *Cyperus*. The terminal inflorescence in *Dulichium* corresponds to that of *Cyperus*, but is raised high above the lateral ones, on account of these being scattered along the stem and borne on relatively short peduncles.

In speaking of the function of the clado-prophyllon in *Cyperus*, we might state at once, that it is by means of this organ that the rays of the umbel attain their more or less horizontal position. This is readily perceivable when we compare a young inflorescence with an older one. Because it is a well-known fact that before the stamens and pistils are fully developed, the rays and the spikes are all erect and congested. But a little before the flowers are ready for fecundation the rays spread out, forcing the involucral, sheathless leaves to attain the same position, and the spikes themselves gradually bend downwards (*Mariscus*) or horizontally (*Cyperus* proper, *Pycreus* and *Diclidium*) by the swelling of the small, basal prophylla (P^2 and P^3). This movement is best noticeable in the large, tubular prophylla (P^1) at the base of the rays, and we might, thus, briefly describe the structure of these organs in order to show, how the movement takes place. The fore-leaves (fig. 2) are tubular with a short, free apex, and they show, when mature, a very prominent swelling at their base and on that face which morphologically is the dorsal; the swelling, sometimes, attains the dimensions and shape like a spur, while the rhachis itself remains slender in its entire length. It is, thus, on the dorsal face of the prophyllon that a parenchymatic tissue rapidly develops, a tissue which in most respects agrees with true collenchyma; it is composed of short, somewhat thick-walled cells without chlorophyll and no mestome-bundles are located in this tissue. The rapid growth of this particular and very local tissue naturally produces a swelling of the leaf-base, and the result is, that the respective ray becomes pushed away from the central and terminal rhachis of the main inflorescence. (R^1 in fig. 1.) Otherwise the structure of the prophyllon shows no deviations from that of an ordinary leaf-sheath.

Although the base of the ray, which is surrounded by the prophyllon, remains slender, it nevertheless possesses some layers of similar, collenchymatic tissue, the presence of which greatly facilitates the movement from the vertical to the horizontal position, forced by the increased growth of the prophyllon. The small fore-leaves at the base of the spikes

* This Journal, vol. iii, p. 429, 1897.

(P^2 and P^3) show the same structure as the larger ones, but they are more open and only tubular at their very base.

This structure of the clado-prophyllon observed in *Cyperus* is, also, to be found in that of other genera, where the function is identical, but not in *Dulichium* or in certain *Carices* where these fore-leaves are enclosed by the sheaths of the subtending bracts, and where the direction of the rhachis or peduncle remains unchanged.

It is now interesting to notice that the involucral leaves and the clado-prophylla, characteristic of *Cyperus*, etc., may be traced in the inflorescence of certain *Gramineæ*.—Several years ago, when we observed this peculiar structure and function of the prophyllon in *Cyperus*, we naturally felt induced to look for this same organ in the inflorescence of other families, wherein the branches are able to perform the same movement from vertical to horizontal in accordance with the development of the flowers. Our attention became especially directed to the *Gramineæ*, and to such genera in which the inflorescence, the panicle, is ample and rich-flowered. We had already studied the vegetative propagation of this order, the *Gramineæ*, as represented in this country, and we had observed several analogies to exist between these and the *Cyperaceæ*, for instance, the invariable presence of a fore-leaf at the base of each lateral, vegetative branch. We had, also, learned that these fore-leaves are "always" open in the *Gramineæ*, but closed, more or less tubular in the *Cyperaceæ*, a point which explains their identity with leaf-sheaths. Among the *Gramineæ* these fore-leaves (clado-prophylla) are very large and quite numerous in such genera of which the shoots are ramified, and they are readily visible, for instance in *Coix*, *Eleusine*, *Panicum*, *Munroa*, and many others. But if we wish now to demonstrate their presence in the inflorescence also, we are obliged to admit that we have, so far, not succeeded in finding them developed as "free" leaves in any of the numerous species which we have examined for this special purpose. The large and open panicle of several species very often exhibits the presence of rudimentary bracts subtending the lateral branches, but these branches themselves do not possess an independent leaf at their base, which might correspond with the tubular prophyllon (P^1) of *Cyperus*; all that is to be seen is a small cushion-like body, which is located at the base of the secondary branches, and on that side of the branch which turns away from the mother-axis. It is, nevertheless, the peculiar structure of this little body which enables the lateral branches to spread out at a certain stage of the flowering period, and considering the fact that its position answers exactly that of a prophyllon, besides that the bract, which subtends the branch, is, also, present as

a mere rudiment, we have felt inclined to consider these organs: the cushion-like body in the *Gramineæ* and the tubular prophyllon (P') in *Cyperus*, as probably being identical formations.

That the bracts, corresponding with the involucral leaves (B') in *Cyperus*, may be observed in the Gramineæ, has been mentioned by some European agrostologists, and they are quite often developed to such extent that their sheath and blade may be distinguished. In a number of species of *Festuca*, *Bromus*, *Schedonorus*, etc., these little bracts are very distinct, at least at the lower secondary branches of the panicle, but they are seldom free, i. e., the sheath and the apex is mostly adnate to the subtended branch. However in *Panicum proliferum* we have observed one instance where the lowermost bract was provided with a free blade about 20^{mm} in length. The structure of this little bract varies within the respective genera, and may prove useful to the distinction of species, as shown by Lange in *Schedonorus*. But in regard to the supposed clado-prophyllon in the panicle of *Gramineæ*, we have not succeeded in detecting any case where this was developed as an open or free leaf, as are the prophylla of the vegetative branches in this same family. However we have noticed some points in their structure which tend to support our opinion about their real morphological identity, that they represent leaves: "fore-leaves."

These organs are quite large in *Zizania aquatica*, and we have seen one case, where one of these cushions was extended into two free tips, simulating the bidentate apex of a prophyllon. It is, furthermore, to be pointed out that in numerous species, and of the most diverse genera, the external structure of these bodies is like that of the leaf-sheaths: when the stem-leaves, and particularly the sheaths, are hairy, the same kind of hairy covering seems constantly to be observed in these cushion-like organs, and when the sheaths are glabrous these organs are, also, glabrous. Another point which we think deserves notice is, that these same organs never surround the branches, but are always, as stated above, located on the upper face only of the respective branch. Their internal structure suggests that which is characteristic of the fore-leaves in *Cyperus*, since we observed a large mass of collenchymatic tissue, which was not in direct continuation with the tissues of the rhachis itself, but was distinctly separated from the peripheral circle of mestome-bundles and their continuous layers of stereomatic tissue. A series of consecutive sections taken from a secondary branch revealed the fact, that the cushion-like body, even if it be adnate to the rhachis, does not in any place constitute a regularly developed tissue as a portion of the rhachis, but that it represents something supplemental and of which the presence does not influence the structure or arrangement

of the tissues of the rhachis proper. When we compare the structure of this organ and of the rhachis with that of a rudimentary bract and the base of the panicle to which it is adnate and with which it forms one solid body, we then perceive exactly the same conditions in respect to the tissues of the bract being well separable from those of the culm, even if they are united into one body, but of two distinct structures. In other words, the internal structure of the cushion-like body resembles that of a clado-prophyllon in *Cyperus* with its large collenchymatic tissue to such an extent, that as far as concerns the structure alone the organs appear to be identical.

Furthermore when we remember that the fore-leaves of *Gramineæ* are open, the position of this little body in the inflorescence may be well comparable with one of these, since it only covers one, the upper, face of the respective branch. Finally, as we have already stated, the function is, also, the same. We, therefore, believe that the small bodies, always observable at the base of the secondary branches of inflorescences in *Gramineæ*, most distinct in large panicles, that these represent rudimentary prophylla, identical with those described above as characteristic of *Cyperaceæ*.

It would be highly desirable if American agrostologists would reëxamine these organs in our *Gramineæ*, for it may be that some genera or species exist in which they are developed somewhat further and more distinctly as foliar organs. But in regard to our own investigations, we can only say that as far as concerns "position, function and structure" these organs may be regarded as rudimentary leaves or "fore-leaves" in this particular case.

Brookland, D. C., July, 1904.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Atomic Weight of Beryllium.*—A series of very careful determinations of this atomic weight has been made by C. L. Parsons of New Hampshire College. Two organic compounds of beryllium, the acetylacetonate, $Be(C_5H_7O_2)_2$, and the basic acetate, $Be_4O(C_2H_3O_2)_6$, were used in this work, both of which are easily purified, since they can be readily crystallized from various solvents, and since they possess the additional remarkable property of subliming unchanged. The compounds, after being weighed, were treated with nitric acid in platinum crucibles, and after evaporation the residues were ignited and the resulting beryllium oxide was weighed. Seven determinations by means of the acetylacetonate gave an average result of 9·113 for the atomic weight (where $O = 16$, $H = 1·008$, $C = 12·01$), while nine determinations with the basic acetate gave exactly the same average. The maximum and minimum results were 9·142 and 9·081. The results agree very closely with the atomic weight 9·1 adopted in the "International" table.—*Jour. Amer. Chem. Soc.*, xxvi, 721. H. L. W.

2. *Connection between the Volatility of Compounds and the Forces at Play within the Molecule.*—The view has been brought forward by Geoffrey Martin that chemically unstable compounds are, as a class, characterized by their volatility and fusibility; chemically stable compounds by their involatility and infusibility. For example, $SiCl_4$, BCl_3, $AlCl_3$, $SnCl_4$, etc., are all volatile and also easy to decompose, while the corresponding oxides are far less volatile and less easily decomposed. It is pointed out, further, that high valency compounds are usually more volatile than the corresponding compounds of lower valency; for instance, $SbCl_5$ is more volatile than $SbCl_3$. This behavior is regarded as due to the greater intensity of chemical forces in the lower valency compounds, as compared with the others. It seems, therefore, that it is the internal chemical forces which the atoms exert on each other in the molecule which decide the external attractive force with which the molecules themselves are attracted together, and, therefore, the volatility of the compound. The author believes that the chemical forces within the molecule determine also the solubility, fusibility, hardness, etc., of compounds, and that if these forces were known it might be possible to calculate mathematically the physical properties of chemical compounds.—*Chem. News*, lxxxix, 241. H. L. W.

3. *Method for the Determination of Chloric Acid.*—This determination is usually carried out by reducing the chlorate to chloride and determining the latter by Volhard's volumetric method. The reducing agents heretofore used have been various ones, such as zinc in some form, ferrous sulphate, etc. Hendrix-

SON has found that metallic iron in the form of "card-teeth" in the presence of 10 per cent sulphuric acid effects this reduction rapidly at ordinary temperatures. At first ferric salts are formed and give the solution a yellow color, but these salts are soon reduced and the solution becomes colorless or slightly green. The reduction requires about one hour at room temperature. The process is applicable to bromates, while perchlorates are not reduced by the operation and hence do not interfere with it. Test-analyses are given which show excellent results, and it appears that the method is a very simple and convenient one.—*Amer. Chem. Jour.*, xxxii, 242. H. L. W.

4. *The Investigation of Double Salts by the Determination of Solubility.*—As a continuation of work by the method devised by Professor Foote of the Sheffield Scientific School, FOOTE and BRISTOL have found that barium and mercuric chlorides, below 17·2°, form the double salt $BaCl_2 \cdot 3HgCl_2 \cdot 6H_2O$. Above this temperature no double salt can be crystallized, although there is evidence that combination takes place in solution, because the solubility of each salt is largely increased by the presence of the other. The double salt thus found is a new one. A compound, $BaCl_2 \cdot 2HgCl_2 \cdot 2H_2O$, described by Bonsdorf about seventy-five years ago, does not exist, at least at 10·4°.

FOOTE has found also that the remarkable double nitrate, $2KNO_3 \cdot Ba(NO_3)_2$, described a year or two ago by Wallbridge, is a true double salt, capable of forming under a rather wide range of conditions. He has shown also that no double salt is produced by potassium and barium chlorides at 25°, although the combination of chlorides is far more usual that that of nitrates. —*Amer. Chem. Jour.*, xxxii, 246; 251. H. L. W.

5. *Nitrous Anhydride.*—It has been known for a long time that mixtures of the gases NO and NO_2 condense to a blue liquid, and it has been shown by Lunge and Porschnew that at −20° the composition of the blue liquid formed by saturating liquid N_2O_4 with gaseous NO corresponds very closely to the compound N_2O_3, or nitrous anhydride. This blue compound, consequently, has been regarded as nitrous anhydride, but up to the present time it has not been shown that the compound exists in the solid state, nor that it is the only compound of the two gases. WITTORFF has recently made fusing-point determination with known mixtures of N_2O_4 and NO, and has found that N_2O_3 exists in the form of blue crystals which melt at −103°, and that no other compound was formed at the temperatures used in the experiments.—*Zeitschr. anorg. Chem.* xli, 85. H. L. W.

6. *A Probable Cause of the Yearly Variation of Magnetic Storms and Auroræ;** by Sir NORMAN LOCKYER and WILLIAM J. S. LOCKYER.—The ordinary meteorological elements, such as atmospheric pressure, temperature, etc., have a yearly change

* From the Proceedings of the Royal Society of London, lxxiv, 90.

satisfactorily explained as due to changes of the position of the earth's axis in relation to the sun, or, in other words, the variation of the sun's declination. There are, however, other phenomena, such as magnetic disturbances and auroræ, which have been explained differently.

Thus, in regard to this seasonal variation Mr. Ellis* has written, "The related physical circumstance is that at the equinoxes, when disturbance is more frequent, the whole surface of the earth comes under the influence of the sun, whilst at the solstices, when magnetic disturbance is less frequent, a portion of the surface remains for a considerable period in shadow."

The object of the present communication is to put forward another possible cause.

It has been previously pointed out† that a very close relationship exists between the epochs of occurrence of prominences in the polar regions of the sun and Ellis's "great" magnetic disturbances. This synchronism showed that either the polar prominences themselves, or the disturbances thus indicated in these polar regions, were the origin of these "great" magnetic storms, or that they were caused by a more general stirring-up of a greater extent in latitude of the solar atmosphere.

A further investigation‡ indicated, however, that in all probability it was either the actual polar prominences themselves, or the activity in the solar polar regions, that initiated these magnetic disturbances, for it was there pointed out that the presence of polar prominence activity-tracks synchronized with the appearances of large "polar" coronal streamers. Here we have an indication of a local cause and effect.

It will be gathered then, that, even as regards terrestrial magnetic phenomena, considerable importance must be attached to action taking place in the regions about the solar poles.

Since the axis on which the sun rotates is inclined to the plane of the ecliptic, there will be times throughout the course of a year when the solar polar regions will be exposed most and least to the earth.

It should be expected, then, that if the polar regions of the sun have any action, as above suggested, the effects of the action on the earth should vary according to the positions of the solar poles relative to the earth.

The actual inclination of the sun's axis being 82° 45′, and the longitude of the ascending node being 74° 25′, or the tilt of the axis being in the direction of about 19 hours in right ascension, it follows that, in each year, the south pole of the sun is most turned towards the earth in the beginning of March (about the 6th), and the north pole most towards the earth in the beginning of September (about the 5th). At the two intermediate epochs,

* Monthly Notices, vol. lxi, p. 540.

† Proc. Roy. Soc., vol. lxxi, p. 244; also Monthly Notices, R.A.S., vol. lxiii, Appendix I, p. 6.

‡ Monthly Notices, R.A.S., vol. lxiii, p. 481.

in June (about 5th) and December (about 6th), neither pole is turned towards or away from the earth, but occupies an intermediate position. Hence we see that the equinoxes occur in the same months as those in which one or other of the solar poles is turned towards the earth, while the neutral positions of the solar poles in relation to the earth occur in the same months as the solstices.

The accompanying diagram [here omitted] shows graphically the relation between the two curves representing the variation of the sun's declination and the change of the latitude of the sun's center or the variation of the amount of the tilt of the solar poles, in relation to the earth throughout a year.

It will be seen that the curve representing the tilt of the solar axis is nearly (a little less than) a quarter of a phase in advance of that indicating the declination change, so that the maximum or minimum point of the latter curve is only slightly in advance of the *mean* points respectively of the former curve.

If, therefore, these solar polar regions are capable of disturbing the magnetic and electric conditions on the earth, as has been above suggested, then, when they are most directed to her at the equinoxes, the greatest effects during a year should be recorded, and when they are least directed the effects should be at a minimum.

It will not be necessary here to refer at any great length to statistics relating to the annual inequality of magnetic disturbances and auroræ, for these have been very efficiently worked out and the results published by Mr. William Ellis.*

Mr. Ellis has shown that the curves of frequency of magnetic disturbances at Greenwich and Paris are very similar, "showing maxima at or near the equinoxes, and minima at or near the solstices." These also, he further points out, are similar, with regard to the epochs of maxima, to the curve representing the frequency of the aurora at London. In the case of auroræ observed in Edinburgh, Northeast Scotland and in different regions in Scandinavia, the months in which the greatest frequency is recorded are September and October (perhaps more generally October) and March and April (perhaps more generally March). Mr. Ellis is inclined to the opinion that there is a small tendency for the autumn maximum to become a little later (from September to October) and the spring maximum somewhat earlier (from April to March) as higher latitudes are approached.

Further, he points out that in more northern latitudes the mid-winter minimum of lower latitudes appears to diminish and eventually disappears, so that the curve of frequency of the aurora between October and March is practically flat with a small intermediate maximum about January. This change in form of the frequency curve in regions in close proximity to the

* Monthly Notices, R.A.S., vol. lx, p. 142; vol. lxi, p. 537; vol. lxiv, p. 229.

magnetic pole, and where the conditions of day and night are so different, is of great interest, but requires careful consideration before it can be regarded as representing real auroral changes.

The accompanying curves [here omitted] illustrate the relation throughout a year between the positions of the earth's poles with reference to the sun; the positions of the sun's poles as regards the earth; the frequency of magnetic storms at Greenwich and Paris; and lastly, the frequency of the aurora as observed at Edinburgh and at stations in Scandinavia below latitude 65° N. The first two curves are those that have already been mentioned, but plotted differently. They have here been so arranged that the maxima points represent the epochs when each of the poles is most inclined to the sun or earth as the case may be. Both the magnetic and auroral curves represent four of the set of curves which Mr. Ellis* has recently published.

It need scarcely be pointed out that the low minima of the auroral curves during the summer months are due in great part to the shortnesss of the nights, and therefore to the restriction of the time available for aurora observations.

The coincidence in time between the epochs of the maxima of the frequency of magnetic disturbances and auroræ, and those of the greatest inclination towards the earth of the north and south solar polar regions is clearly indicated.

It is interesting to inquire in what way this yearly inequality of terrestrial magnetic phenomena is influenced when the sun's polar regions are, for different groups of years, in an undisturbed and disturbed condition.

It would be expected that the oscillation of more disturbed solar polar regions towards and away from the earth would tend to *increase the difference* between the frequency of magnetic disturbance at the equinoxes and solstices, while this difference for those years when the less disturbed solar polar regions are in action should be somewhat *reduced*. That this is actually the case is brought out by the figures which Mr. Ellis has given in the publication of which mention has already been made.

Since the greatest magnetic storms are closely associated in point of time with prominence disturbances in the polar regions of the sun, to make the necessary comparison, therefore, the years in which "great" magnetic storms occurred should be grouped together and the yearly inequality determined, and another group of years in which "great" magnetic storms were less frequent formed and the yearly inequality also determined. Fortunately a computation already made can be utilized for this comparison, for Mr. Ellis has determined the number of days of greater frequency (near sunspot maximum), and lesser frequency (near sunspot minimum), of magnetic disturbance, both groups practically including the conditions required. Thus he has formed groups of the years 1848–51, 1858–61, 1869–72, 1882–85, 1892–95, which include, at any rate for the last three groups, the years where

* Monthly Notices, R.A.S., vol. lxiv, p. 229.

prominences were in high latitudes, and another series of groups of years, 1854–57, 1865–68, 1876–79, 1887–90, which are years when prominences were less frequent in these regions.*

The interesting conclusion to which Mr. Ellis arrived was that "the excess of the equinoctial frequency over the solstitial frequency is greater, the greater the degree of disturbance."

This result thus helps to endorse the suggestion made in a previous paragraph that the greater the disturbed solar polar regions, the greater the difference between the magnetic frequency at the equinoxes and solstices.

Conclusions.—The conclusions arrived at in the above paper may be briefly stated as follows:

1. The seasonal variation in the frequency of magnetic storms and auroræ depends on the position of the sun's axis in relation to the earth.

2. The epochs of the greatest inclinations of the sun's axis towards or away from the earth, or in other words the greatest exposure of the N. or S. solar polar regions to the earth during a year, correspond to those of greatest magnetic and auroral frequency.

3. The epochs (groups of years), when the solar polar regions are most disturbed, synchronize with those when the excess of the equinoctial over the solstitial frequency of magnetic storms is greatest.

7. *Physikalische Technik, oder Anleitung zu Experimentalvorträgen sowie zur Selbstherstellung einfacher Demonstrationsapparate.* Seventh Edition. By Dr. Otto Lehmann. Pp. xx + 630. Braunschweig (Friedrich Vieweg und Sohn).—This is the first part of volume one of Dr. Joseph Frick's well known work. In this edition the book has been entirely rewritten and very much enlarged. In its present form it is an exhaustive compendium treating of the objects, methods and materials of the experimental lecture as a branch of instruction in Physics. This part of the work is concerned with the arrangement of the lecture and preparation rooms and the workshop. All the details of the installations for the electric, gas, water, steam, air pressure and vacuum services and all the non-portable parts of the lecture-room outfit are gone into with the greatest thoroughness. The portion on the shop will be of value to the worker in the laboratory as well as to the lecturer. This part occupies nearly half the book and contains numerous methods, recipes, etc., of use

* The fact that continuous observation of solar prominences was only commenced in 1870 accounts for our lack of knowledge of the frequency of this class of phenomena before that date. Since, however, during the last three sunspot cycles it has been observed that polar prominences are most frequent just a little after a sunspot minimum and up to and at the epoch of the following sunspot maximum, it may be concluded that their appearance previous to the year 1870 occurred at the same time in relation to the sunspot cycle. Ellis's groups of years previous to that date, namely, 1848–51 and 1858–61, may on these grounds be classed as years in which polar prominences were present, whilst the groups 1854–57 and 1865–68 may be taken as epochs when polar prominences were not so frequent.

to the instrument builder, as well as instruction in the arts of forging, soldering, glass-blowing and cutting, lacquering, etc. In addition there are many useful hints on the working and handling of materials such as quartz, amber and porcelain. The camera and dark-room as adjuncts of the lecture, especially the making of slides and the art of photo-micrography, are extensively treated. In fact, one can hardly think of anything in the organization and equipment for this side of physical instruction, from the clerical work of the office to the chemical room, that is not treated. Altogether this is a most valuable book. L. P. W.

II. GEOLOGY.

1. *Recent Studies of the Moon's Features* (Communicated by J. Barrell).—Within the past year have appeared two notable contributions to the literature of the moon's surface. One is by Professor N. S. Shaler,* the other by Professor W. H. Pickering† and they represent divergent views. Professor Shaler remarks in the Preliminary Note: "The ends sought have been those alone which had distinct reference to geology. . . In fact almost all the questions brought up by studies on the satellite are more or less entangled with those relating to the evolution of the planet, so that except for the detailed account of the features of either body they must needs be considered together. These features may be compared by types, and in the main the following essay consists of such comparisons."

The craters are so different in size from those of the earth, many being over a hundred miles in diameter, and so numerous, overlapping and irregularly distributed that the causes leading to their formation must be very different from those of volcanoes upon the earth, and for these forms Shaler proposes the name of vulcanoids. The maria, or great plains, evidently belong to a category distinct from the vulcanoids, being characterized by their larger size, smoother and darker floors, and it is suggested that they may be caused by the infalling of large meteors. It would seem, however, that the attempt to provide a meteoric origin for the maria, but not for the craters, would lead into grave difficulties. While the evident fluidity of the lavas which formed them distinguishes them sharply from the steep, rough walls of the vulcanoids, yet in degree of fluidity and in area covered they have not so far exceeded the great lava flows of the western United States and the Deccan of India. The mountainous reliefs

* A Comparison of the Features of the Earth and the Moon, by N. S. Shaler, Professor at Harvard University. Smithsonian Contributions to Knowledge, vol. xxxiv, 79 pp., 24 plates.

† "The Moon, a Summary of the Existing Knowledge of our Satellite, with a complete Photographic Atlas," by William H. Pickering of Harvard College Observatory. 103 pp., 100 plates. New York, Doubleday, Page & Co. The text is a semi-popular treatment of matter already published in vols. xxxii, part I, 1895, part II, 1900 and vol. li, 1903 Annals of the Astronomical Observatory of Harvard College.

are classed under a number of heads, certain wrinkles upon the surfaces of the maria appearing to correspond to the usual earth type of mountains due to crustal shortening; the other types appearing to have had an igneous origin and to be formed of viscous lavas which have solidified with very steep slopes. Clearly marked faults are rare upon the moon, though cracks, as indicated by the so-called "rills," are abundant.

The almost complete absence of evidence of shrinkage and consequent tangential or mountain-making thrust is one of the greatest fundamental distinctions between the history of the earth and its satellite and for a better understanding of which we may have to await a fuller knowledge of the causes of terrestrial contraction.

The ray systems, whitish streaks which radiate from certain of the prominent craters to distances of several hundred miles, crossing plains and vulcanoids alike, are among the most enigmatical features of the moon's surface, becoming strongly visible only about two days after sunrise and disappearing at a somewhat lesser interval before sunset. The author concludes that they are probably fumarolic deposits within and upon the crust from extremely deep-seated fissures and that they are of ancient origin, a view which precludes their consisting of ice, since in that case a gradual evaporation and dispersal of the water vapor would take place at even the lowest temperatures. They are regarded as most probably due to some crystalline and fluorescent material which does not reflect the sunlight until a considerable elevation has been attained.

Considering that these ray systems are of considerable geological antiquity, the author raises the question as to why in a sphere free from erosion they have not become veiled by meteoric dust. Of a number of suggestions presented to explain this feature the most reasonable are that either the amount and importance of meteoric dust received by the earth and moon have been greatly overestimated, or else that we have misjudged the age of the moon's surface and the ray systems are not of great antiquity.

As to the permanence of the lunar relief, it is evident from an examination of the plates "that there is some agent which has operated to break down the more ancient topographical features. There is an evident difference of aspect between the walls of the older vulcanoids and those of newer formation." In fact all stages of obliteration may be traced to large nameless vulcanoids whose ruins only a careful examination will reveal. As water has evidently never acted, the most probable cause is assigned to be alternate expansions and contractions of the superficial crust during the lunar day and night. Whatever the agent of decay may be, the numberless superpositions of vulcanoids and the extremely ruined character of the most ancient is indicative of a long and complex volcanic history. Professor Shaler as the result of his studies disbelieves in any atmosphere or present volcanic activities even of solfataric stages, but in view of the

recent studies to be mentioned later these views may be too extreme. In regard to the question of vegetable life upon the moon it is very properly stated that other possible explanations should be sought to account for the darkening of certain areas at lunar midday in preference to believing them due to vegetable growth. Against the existence of even vegetable life upon the moon it is urged that no terrestrial life exists upon mountain slopes 20,000 feet or more above the sea under atmospheric and thermometric conditions which must be vastly more favorable than those to be found upon the moon. Furthermore, whatever were the circumstances, as yet unknown, which led to the beginning of life upon this earth, they were evidently of rare occurrence. "The fate of our satellite was probably in large part determined by the ratio between its gravitative force and the energy of the kinetic movement of the gases such as constitute the atmosphere. If that energy had been sufficient to retain them on the satellite, there is no reason, at least so long as the original rotation on its axis continued, why it should not have had the history of a miniature earth."

The plates are from photographs in the possession of the Smithsonian Institution and have been taken at the Lick, Paris, and Yerkes Observatories. They are all extremely fine reproductions on several different scales selected with reference to the questions discussed in the text and may be considered as a separate contribution by the Smithsonian Institution to Selenography.

"The Moon," by Professor Pickering, although written in a popular manner, is issued as a scientific book intended for an intelligent class of readers who are not astronomers, and it must be criticized on that basis.

The first three chapters present the commonly accepted views as to the origin of the moon, the data in regard to its distance, rotation, etc., and views arrived at within a few years by the writer and others regarding the density and temperature of a lunar atmosphere.

In another chapter under the subject of artificial craters, the author cites the blow holes formed on the surface of pots of solidifying slag, and also gives the results of experiments upon paraffin, especially where a pumping motion was given to the still molten portions beneath the solidifying crust to simulate subcrustal tidal waves. By this means he was able to obtain the appearance of lunar craters. It may be remarked, however, that even if the craters were all made during that distant time when the moon still retained an axial revolution faster than its orbital revolution about the earth, a conclusion which Pickering himself apparently does not accept, it would be impossible for a solid crust to maintain such rigidity that the lava communicating with a molten interior could rise and fall to an appreciable extent through tidal action. On the contrary, as in the case of the earth, the whole spheroid would yield. This weakness is pointed out by Professor Shaler. The hypothesis is furthermore based

upon the old idea, of an outer crust and a fluid interior, though it has never yet been proved that at any time in the cooling of a planet would such conditions exist.

As it would appear impossible, therefore, to account for the lunar craters by a hypothesis of tidal action upon a fluid interior, it must be confessed that their fundamental differences point to an origin unlike any volcanic features of the earth, and we are still far from an understanding of them.

Under the subject of active lunar craters and river beds, the author describes changes which have been observed in certain lunar craters, which have led him to the belief that volcanic activity has not ceased upon the moon, and that water vapor which immediately turns into clouds of hoar frost is given off from certain craters. In the following chapter it is maintained that the greater brightness of many crater rims and likewise the bright streaks radiating from a number of the principal craters consist of snow.

In the earlier chapter upon the lunar atmosphere, water, and temperature, the author gives good observational grounds for believing that an atmosphere exists at the moon's surface, comparable in density to that of the earth at a height of from 40 to 45 miles above the surface. In addition, a haze appears to rise to a height of from three to four miles upon the sunlit side of the moon, but is absent from the unilluminated portion.

Accepting the facts of observation, the extremely questionable side is in the interpretations given them. It has been shown by Stoney that water vapor would escape with great rapidity from the moon and carbon dioxide somewhat more slowly. It would seem extremely improbable, therefore, that these two gases should at the present time be undergoing elimination from the body of the moon, at such a rate as to constitute even such a rare atmosphere as is found or permanent snow fields. Such a hypothesis, while explaining with apparent satisfaction the observed enlargement of the white spots of Linné toward lunar sunset and during a lunar eclipse, as due to a sublimation of hoar frost, is peculiarly difficult of application to the system of rays, and both the atmosphere and rays may consist of some other substances. Until some means is found of proving their nature, some of the suggestions offered by Professor Shaler would appear more reasonable.

Finally in the chapter upon "*Vegetation: the Lunar Canals*," the writer gives his reasons for believing that a luxuriant vegetation exists upon the moon. The evidence for this extreme view is based entirely upon the darkening of certain areas, and their increase of size during the lunar morning, and their disappearance shortly before the time of sunset.

Since conditions so unfavorable to life exist upon the moon, the hypothesis of vegetation should apparently be the last to be sought as an explanation for these mystifying phenomena. An outline of Professor Shaler's criticisms has already been given, and it may be said in addition that for any form of lunar life to

exist not only would it have to originate and evolve into something higher than primordial forms under atmospheric conditions incompatible with life as we know it, but that the conditions of temperature would likewise appear to preclude such a view. While our knowledge of lunar temperatures has been in times past very imperfect, it may be well to quote Professor Very's* more recent and carefully ascertained results. "In conclusion, it seems to me reasonably certain that a large part of the Moon experiences daily great vicissitudes of temperature. Its rocky surface at midday, in latitudes where the sun is high is probably hotter than boiling water; and only the most terrible of Earth's deserts, where the burning sands blister the skin, and men, beasts, and birds drop dead, can approach a noontide on the cloudless surface of our satellite. Only the extreme polar latitudes of the moon can have an endurable temperature by day to say nothing of the night, when we should have to become troglodytes to preserve ourselves from such intense cold."

Although as Professor Very remarks, the noontide temperature may be lower and the life conditions in that regard possibly more favorable than if the moon possessed an atmosphere comparable to our own in density, scientists in general and biologists in particular will be loath to accept a belief in life of any sort upon the moon until at least all other and inorganic hypotheses have been exhausted.

It is regretable that when a scientific volume is put forth for a public who are not specialists, that such doubtful interpretations should be stated as though they were well established and well accepted scientific truths.

The plates show in a systematic manner all visible portions of the moon's surface under five different degrees of illumination, on a scale of $5'' = 1^{mm}$, giving a lunar diameter varying from 14 to 16 inches. As pointed out on p. 97, this is the only complete photographic atlas of the moon in existence, and not only so but it covers the whole visible surface of the moon five times. As the scale is rather small, however, the plates are chiefly useful in studying general features of the moon.

2. *Cretaceous Deposits of the Pacific Coast;* by FRANK M. ANDERSON. Vol II, No. 1, 3d Series, California Academy of Sciences, 146 pp., 12 pls.—The Cretaceous deposits of the Pacific Coast of North America lie within a narrow continental border mainly to the west of the Great Basin and the northern Cordillera. Southward the only deposits of the Pacific province known are isolated ones in Mexico and Chili. In the description of these beds there are given for the first time in a connected account the essential faunal and physiographic facts. The divisions recognized in the Sacramento Basin are:

(1) The Knoxville horizon, several thousand feet in thickness and extending to the upper limit of known species of *Aucellas*,

* The Probable Range of Temperature on the Moon, The Astrophysical Journal, vol. viii, Dec., '98, p. 286.

the fauna being essentially boreal. (2) The Horsetown horizon, beginning with the close of the Knoxville and continuing to the horizon representing the great Chico overlap, the fauna being typically subtropical. (3) The Chico or uppermost member as represented by the Phoenix beds, and by those of Wallala and other points in Lower California. The Chico is divisible into two horizons in the Sacramento Basin, and perhaps elsewhere, the later Chico fauna being characterized by a large development of gasteropods and lamellibranchs.

The general order of regional movement, more particularly in the Great Valley, has been downward from the first, but not continuously so. The different members of the Cretaceous series of California find their counterparts all along the American border of the Pacific, and are to be closely correlated with the recognized members of the interior basins of both hemispheres, as shown by a parallelism of crustal movement and development much more general than commonly supposed, and by extensive faunal resemblances, amounting often to close specific affinity or even specific identity. The faunæ of the Pacific coast Cretaceous are mostly marine, and of littoral rather than deep-sea origin. G. R. W.

3. *Geology of German Southwest Africa.* — At a meeting of the Geological Society of South Africa, held at Johannesburg, July 11th, 1904, Mr. F. W. Voit presented a paper on the geology of the region east of Walfish Bay and between the Quisep and Swakob Rivers.

The country is in large part desert, covered with quicksands and sand dunes. The greater part of the country exhibits the same geological features as the oldest members of the geological formation in South Africa. The base of the district consists of schistose rocks, exhibiting large variety ranging from fine schists to coarsely banded gneisses. These metamorphic rocks are ascribed to the Archean Period. The amphibolite layers in the gneisses are believed to be extrusives of a diabase type. There are also intrusive masses of granite. A few outcrops of sandstone occur and are classed as Lower Devonian. The appearance of copper ore in this district has been investigated by Mr. Voit, and it seems probable that extensive deposits of medium grade ore will be found. It is of interest to note that volborthite (which is elsewhere a rare mineral) is of very frequent occurrence in this district. The rocks collected have been studied microscopically by Professor Beck, of Freiburg.

4. *Liassic and Oolitic Floras of England.*—Being Part II of the Jurassic Flora represented in the British Museum; by A. C. Seward. 183 pp., 13 pls.—This number of the British Museum catalogue forms the completion of a treatise on fossil floræ of the Trias, Rhætic, Lias, and Oölite of England. Although the fossils included in Part II are for the greater part fragmentary, the high degree of care bestowed on this as on all the parts gives the descriptions importance in themselves aside from the fact that they belong to a series that is indispensable to every student of fossil plants and plant distribution.

Among special features of Part II there perhaps only needs to be here mentioned the fact that two small leaves with a decidedly dicotyledonous appearance are figured (Plate XI, figures 5 and 6) from the rocks of the Great Oölite of Stonesfield, as belonging to the "convenient genus" *Phyllites*. This Seward would have restricted for the designation of Dicotyledonous leaves that cannot with certainty be referred to a particular family.—In commenting on the extremely scanty occurrence of Jurassic dicotyls Seward says, and the reviewer has similarly expressed himself,—"There is, in short, no *à priori* improbability that Dicotyledons existed ages before they attained to a position of importance, and it is highly probable that this was the case." The fundamentally important statement is also made that, "We cannot deduce any evidence from such data as we possess in favor of the existence of well-defined botanical provinces during the Rhætic, Jurassic, or Wealden periods." G. R. W.

III. Miscellaneous Scientific Intelligence.

1. *British Association.*—The annual meeting of the British Association for the Advancement of Science was held at Cambridge during the week from the 17th to the 24th of August. The inaugural address upon the subject* "Reflections suggested by the new Theory of Matter" was delivered by the President, the Right Hon. A. J. Balfour. The attendance at the meeting was 2,789, which has only been exceeded on five occasions. The meeting of next year is to be held at Cape Town, South Africa, and Dr. George H. Darwin has been elected President.

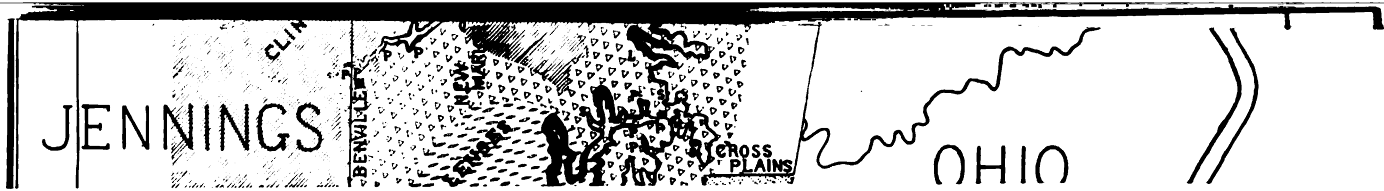
2. *The Metric Fallacy;* by Frederick A. Halsey. *The Metric Failure in the Textile Industry;* by Samuel S. Dale. Pp. 231. New York, 1904 (D. Van Nostrand Co.).—This is a somewhat caustic arraignment of the metric system based upon a paper presented to the American Society of Mechanical Engineers in December, 1902. The authors claim that the actual introduction of the system, in countries where it is sanctioned by law, is less complete than has been supposed, from the standpoint of its practical application in the arts, and give reasons why they believe its introduction in this country to be undesirable.

Scientific workers believe strongly in the simplicity and value of the metric units, but it is fair that the subject should also be discussed from the standpoint of its practical application to the useful arts.

Obituary.

Dr. Joseph D. Everett, for upwards of thirty years Professor of Natural Philosophy at Queen's College, Belfast, died on August 9 at the age of seventy-three years. His excellent translation of Deschanel's Natural Philosophy has been long known and highly valued by students of physics. His book on the C. G. S. system of units, published when the selection of practical units in electricity was under discussion, was an important contribution which has had a wide influence. He was also the author of numerous papers, largely on theoretical subjects.

* See Nature for August 18, also the same number and those immediately following for the addresses by the Presidents of Sections.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[FOURTH SERIES.]

ART. XXXVI. — *The Ordovician-Silurian Contact in the Ripley Island Area of Southern Indiana, with notes on the age of the Cincinnati geanticline;* by AUG. F. FOERSTE. (With Plate XVII.)

Cincinnati Geanticline.

THE axis of the Cincinnati geanticline, a low fold, extends from the northern part of Alabama through central Tennessee and Kentucky into southwestern Ohio and the adjacent part of Indiana. Northward it branches, one axis reaching the western end of Lake Erie,* the other extending northwestward across the northern half of Indiana† into northern Illinois. In Tennessee the rocks dip southeastward as far as Walden Ridge and Cumberland Mountain, a distance varying from 75 to 100 miles; on the western side of the axis the dip is westward or northwestward at least as far as the Tennessee river, a distance of 100 miles; farther west, the Tertiary deposits conceal the Paleozoic rocks involved in the fold. In the southern half of Kentucky the rocks dip westward for a distance of at least 100 miles. From the northern half of Kentucky the dip is westward across the state of Indiana as far as the eastern part of Illinois, a distance approximately of 200 miles. Northward, the rocks dip westward from the western branch of the axis across Indiana and the eastern third of Illinois. Eastward, the rocks dip from the eastern branch of the axis across the state of Ohio as far as western Pennsylvania and the western part of West Virginia, the maximum distance being at least 180 miles.

Over the greater part of the area the dips are too low to be detected from any single point of view. As a rule, however, a comparison of levels of corresponding strata from exposures

* Ohio. Geol. Surv., vi, 1888, map opposite p. 48.
† Indiana Geol. Surv., 18th Rept., 1894, p. 221.

several miles apart gives unmistakeable evidence of dip. Locally the dips may be conspicuous though rarely exceeding 30 degrees; however, the local nature of these dips is detected easily, and usually is connected with folds and domes of rather small extent. These local folds and domes are much more numerous in the southern half of Kentucky and in Tennessee than in the northern half of the area affected by the geanticline, although tilted rocks are not uncommon along the western branch of the axis in northern Indiana.

The rocks involved in the folding include all of the Paleozoic formations. Ordovician strata are exposed along the greater part of the axis between northern Alabama and a point 26 miles north of Dayton, Ohio, a total distance of 400 miles. In the southern half of Kentucky there is a sag along the axis in consequence of which the crest of the geanticline is formed by Mississippian (sub-Carboniferous) strata. North and south of this sag of the axis, along the crest of the geanticline, are two areas of considerable extent in which the Ordovician exposures are practically continuous. Of these the southern area,* 75 miles long and nearly 50 miles broad, includes all of central Tennessee The northern area,† 150 miles long and 85 miles broad, includes the northern part of Kentucky and the adjacent parts of Ohio and Indiana, between the towns of Lebanon, Richmond, and Maysville, Kentucky, Dayton, Ohio, Richmond, and Madison, Indiana. That part of the Cincinnati geanticline including the southern Ordovician area is occasionally referred to as the Nashville dome, while the part including the northern Ordovician area is sometimes called the Kentucky uplift or Cincinnati dome. Farther northward in Ohio‡ and Indiana§ the crest of the eastern and western branches of the Cincinnati geanticline is formed by Silurian strata.

Silurian Strata of Geanticline.

No trace of the Lower or Oswegan division of the Silurian, including the Oneida and Medina, is exposed anywhere in the area affected by the Cincinnati geanticline. Middle Silurian or Niagaran exposures, however, ranging from the Clinton to the Guelph, are abundant. Cayugan or Upper Silurian exposures, including rocks formerly known as Waterlime,‖ are known to occur in several areas but have not been studied. In

* Geology of Tennessee, by James M. Safford, 1869, map.

† The Richmond group along the western side of the Cincinnati anticline in Indiana and Kentucky, Am. Geol., 1903, pl. 20; Silurian outcrops indicated by dotted line.

‡ Ohio Geol. Surv., vii, 1893, map.

§ Indiana Geol. Surv., 19th Rept., 1894, map; much more accurate map now in press.

‖ Silurian and Devonian limestones of western Tennessee, Journ. Geol., xi, 1903, pp. 701, 702.

Ohio, Cayugan formations extend from the western Put in Bay islands in the western part of Lake Erie into Lewis county in northern Kentucky, crossing the Ohio river at Vanceburg, Ky. In Indiana, Cayugan strata are known only from Kokomo, although their occurrence in northeastern Indiana has been considered probable.

In Indiana, the Niagaran has been divided into the following subdivisions, named in descending order: Louisville, limestone; Waldron, clay; Laurel, limestone; Osgood, clay and limestone; Clinton, limestone.

Pre-Meso-Devonic origin of the Cincinnati Geanticline.

Along the western flank of the geanticline, in Kentucky and Tennessee, the edges of these subdivisions of the Niagaran, where not covered by overlying subdivisions of the same Niagaran series, thin out eastward toward the Ordovician axis,* and are overlaid unconformably by Middle Devonian limestones or by Devonian black shale. Along the eastern flank of the geanticline, in Kentucky, the uncovered edges of Silurian formations equivalent to the Clinton and Osgood beds thin out in a similar manner westward toward the same Ordovician axis and are also overlaid uncomformably by Middle Devonian limestones or by Devonian black shale. No Silurian rocks are exposed along the eastern margin of the Ordovician area in Tennessee. However, their presence in the Sequatchie valley indicates that Silurian strata exist also along the eastern flank of the geanticline in Tennessee, but are concealed by the cover formed by later strata. The character of the unconformity between the Niagaran and Devonian formations places the origin of the Cincinnati geanticline in times preceding the Middle Devonian.

Pre-Niagaran origin of Geanticline.

Inconclusive nature of certain arguments advanced.—In western Tennessee, Professor Safford and others thought they could trace the upper Niagaran formations up the western flank of the geanticline, farther eastward than the lower Niagaran formations, the former overlapping the latter. From this they concluded that the origin of the Cincinnati geanticline took place in times preceding the deposition of the Niagaran. More recent investigations have not confirmed this overlapping of the upper Niagaran formations, so that this argument becomes ineffective. Other writers have regarded the thinning of the Silurian formations from the flanks toward the crest of the geanticline as sufficient evidence of pre-Niagaran origin.

* Silurian and Devonian limestones of Tennessee and Kentucky, Bull. Geol. Soc. Am., xii, pp. 398, 422. The Cincinnati anticline in southern Kentucky, Am. Geol. 1902, pl. 26; Am. Geol., 1903, pl. 20.

This argument also has lost force since it has been discovered that along the western flank of the geanticline the conspicuous thinning of Niagaran formations toward the east is confined to the edges* of the Niagaran formations, where in succession they project from beneath the immediately overlying Niagaran beds on approaching the crest of the geanticline; and where the thinning of the strata might have been caused by erosion subsequent to their deposition. The same strata fail to show any conspicuous thinning eastward where the immediately following subdivision of the Niagaran is present. Under these conditions it is not possible, without further evidence, to exclude the alternative proposition, that the Niagaran, at least the Clinton and the equivalents of the Osgood clay, originally may have extended across the region of the present Cincinnati geanticline, gradually thinning out westward; that during late Silurian or early Devonian times a geanticlinal uplift occurred, accompanied by removal of Silurian strata along the crest of this uplift and resulting in a conspicuous thinning of the edges of the various Niagaran strata toward the crest of the geanticline whereever exposed by the removal of overlying Niagaran formations. This alternative proposition would demand the operation of geological processes resulting in baselevelling, the Devonian formations being deposited upon the baselevelled edges of the Niagaran. It should be remembered however that, at present, evidence favoring baselevelling of Niagaran strata is confined to the conspicuous thinning of the edges of Niagaran formations toward the crest of the geanticline where not protected by the next overlying Niagaran formations, and the absence of a similar conspicuous thinning in the same direction where the next overlying Niagaran formation is present. It seems scarcely possible that baselevelling could have taken place over areas as large as those exposed along the crest of the Cincinnati geanticline without leaving other evidence than that offered by the thinning of strata as just described.

During the earlier operations of the Geological Survey of Ohio under Professor Orton, thin layers of conglomerate were discovered in the Clinton at Belfast† in Highland county, 57 miles east of Cincinnati, Ohio. The fossils in the pebbles of this conglomerate were believed to have been of Ordovician age, but subsequent investigations proved their Clinton origin, and that older strata of Clinton age had been broken up during the formation of this conglomerate. The presence of conglomerate was believed to be conclusive evidence of the pre-Niagaran origin of the Cincinnati geanticline. It is scarcely neces-

* Silurian and Devonian limestones of Tennessee and Kentucky, Bull. Geol. Soc. Am., 1901, pp. 408–414, fig. 5.

† Ohio Geol. Rept., Surv. for 1870, p. 270. On Clinton conglomerates and wave marks in Ohio and Kentucky, Journ. Geology, iii, 1895, pp. 1-4, 22–26.

sary to point out the inconclusiveness of this evidence founded on observations at a single locality; however in view of opinions as to the age of the Cincinnati geanticline then generally current, the predication of the pre-Niagaran origin of the geanticline on the basis of this Belfast exposure of conglomerate is certainly comprehensible. Moreover, it is not impossible that at some future time, in combination with other evidence not yet at hand, it may prove to have an important bearing upon the subject.

More recent observations upon the Clinton of Indiana have brought to light facts which are of interest in this connection.

Ordovician-Silurian Contact in Ripley Island Area of Southeastern Indiana.

Base of Silurian.—When the investigation of Silurian strata in Indiana was begun, the pre-Silurian origin of the Cincinnati geanticline was accepted. In Ohio the Clinton was known to become thinner westward. Near the Ohio river, in Adams and Highland* counties, exposures equalling 35 feet, in some instances possibly 40 feet, are seen. Northwestward, in Clinton county, the Clinton has a thickness of at least 25, possibly 30 feet. Still farther northwest, east of the Miami river, in the northeastern part of Montgomery and the southeastern part of Miami county, the thickness varies between 23 and 28 feet. Passing from the northern half of this northwesterly running line of outcrop toward the southwest, the rate of diminution of the Clinton is much more rapid. At Sunderland Falls and at Ludlow Falls the thickness is about 22 feet. At Fauvers quarry, 2 miles north of Dayton, west of the Stillwater river, and at Centreville, 9 miles south of Dayton, the thickness is 17 feet. At the Betty Heidy exposure, about a mile east of Oregonia, the thickness is at least 14 feet, and possibly equalled 16 feet. At the Soldiers' Home, west of Dayton, it is about 15 feet. At Lewisburg and Eaton, the thickness is 13 feet. East and southeast of Richmond in Indiana it is about 11 feet. About 12 miles southwest of Eaton, six miles east of the state line, the thickness does not appear to exceed nine feet.

The decrease in thickness of the Clinton toward the southwest continues in Indiana.† Glacial deposits cover the Clinton in the western part of Wayne county, but in the western part of Fayette and Franklin counties the thickness of the Clinton usually does not exceed 6, but occasionally attains 8 feet, and frequently is reduced to 4 feet or even less. Southward, across the center of Ripley county, the thickness of the Clinton con-

* An account of Middle Silurian rocks of Ohio and Indiana, Journ. Cincinnati Soc. Nat. Hist., xviii, 1896.

† Indiana Geol. Surv., 21st Rept. p. 213; and 22nd Rept. p. 195.

tinues to diminish, but southwestward, in the western part of Ripley and the adjacent parts of Jennings and Decatur counties, the Clinton is entirely absent. These facts were entirely unexpected. In keeping with preconceived views of the early, pre-Silurian origin of the Cincinnati geanticline, it was believed that after crossing the axis of the geanticline the thickness of the Clinton would increase instead of decrease westward. Instead, a fairly regular decrease in thickness across the axis of the geanticline was noted, beginning with the most northeastern exposures in Ohio, and continuing to the most southwestern of the series of exposures so far discussed.

The area, or areas, from which the Clinton is absent is here called the Ripley island or islands. The outlines of this area are known only along the eastern border, and even here much remains to be determined. The facts so far discovered are indicated on the accompanying map (Plate XVII). East and southeast of the Ripley island area the Clinton contains pebbles.

These pebbles which occur in the Clinton are usually confined to the lower 4 to 6 inches of the formation. They are commonly not more than an inch in length, although pebbles 2 and even 3 inches in length are recorded from several localities, and at one locality thin flat pieces of rock, 6 to 8 inches in length, were included. Most of these pebbles consist of a very fine-grained white limestone, belonging to the very top of the Ordovician of this part of Indiana. The most common fossil in this white rock is *Tetradium minus*, but this rarely appears in the pebbles. Not infrequently the white limestone occurs directly beneath the Clinton; occasionally in such situations it is cracked and the cracks are filled with the salmon-brown detrital material of which the Clinton is formed in this part of Indiana; the contrast in color is striking. Occasionally the white limestone is cracked also where it occurs at some distance beneath the Clinton and the cracks are filled with clay. Sometimes worm-borings penetrate for several inches into the top of the white limestone, and the cavities are filled with the salmon-brown Clinton material. The pebbles formed from this limestone are frequently very angular in shape, sometimes having the appearance of derivation from some brecciated rock, at other times with the corners conspicuously rounded. It appears that before the deposition of the Clinton, this white limestone was a soft calcareous mud into which worms could bore; owing to shrinkage it cracked into rather small irregular fragments; this shrinkage may have been caused by drying owing to exposure of the surface to the sun; the surface of the Clintonless area may have been in the condition of flats within the reach of high tides; the fragments produced by cracking were often washed toward regions of deposition; those longest exposed to the air

and most hardened, and those transported the shortest distance, were left most angular. Occasionally fragments of Ordovician limestone, formed by the detrital remains of shells and bryozoans comminuted so as scarcely to be recognizable, have been caught up by the Clinton. In these cases the fragments of limestone consist usually of thin slabs. It appears that this limestone of detrital origin solidified more rapidly than the very fine-grained mud forming the white limestone, probably because the detrital limestone permitted a freer circulation of water. In these detrital limestone pebbles *Rafinesquina alternata* and other Ordovician fossils are found. The localities from which pebbles in the Clinton have been recorded are indicated on the map by the letter P; they undoubtedly include only a small part of the localities at which pebbles occur.

South of Laurel, those exposures of the Clinton which indicate a detrital origin usually have a salmon-brown color. The detrital material usually is fairly coarse. The absence of the finer material which must have resulted from the attrition is probable due to currents which were strong enough to sweep along the finer material but left the coarser particles behind to form the Clinton deposit. Sometimes this fine-grained material appears to have been allowed to deposit for a short time, producing thin layers, but as a rule these layers were swept away again later; however their former existence is suggested by the presence in the salmon-brown Clinton of thin lenses of fine-grained whitish limestone, usually widely separated but sometimes connected by very attenuated sheets of the same material. Some of the localities at which these white lenses occur in the salmon-brown Clinton are indicated on the map by the letter L. The lack of distinct bedding or the presence of cross bedding is another evidence of the deposition of the Clinton under the influence of rather strong, irregular currents.

Where the Clinton is absent in Indiana, the lowest layers of the Osgood rest directly upon the Madison bed. At one locality 4 miles west-southwest from Osgood, a single pebble of salmon-brown Clinton rock with blotches of black was found enclosed in the white limestone forming the base of the Osgood beds, 2 inches above the Ordovician. The pebble was 3 inches long, almost 3 inches wide, and half an inch thick. This is the only pebble found at any point in the Osgood bed. Immediately beneath was clay with *Tetradium*, and farther down occurred limestone including concretionary masses or some species of *Strephochetus*.

The presence of areas from which the Clinton is absent, surrounded by areas in which the Clinton contains pebbles of Ordovician origin, is an indication of course of unconformity

between the Silurian and Ordovician in this area. In seeking to determine the measure of the erosion of Ordovician rocks in times preceding the deposition of the Silurian in the Clintonless areas, it was expected that the Silurian would be found to rest upon Ordovician rocks of a considerably lower horizon where the Osgood rested directly on the Ordovician, than at more remote points where the Clinton was present and the pebbles were absent. No striking difference was noted. The detailed observations are presented on the following pages.

Top of Ordovician.—In Indiana, Ohio, and Kentucky, the Cincinnati group at the top of the Ordovician is divided into the Utica, Lorraine and Richmond, named in ascending order. The Richmond is further subdivided into the Waynesville, Liberty, Whitewater, and Madison beds, also named in ascending order. The Madison bed has also been called the Saluda bed, since the name Madison was employed earlier elsewhere. The thickest exposures of the Madison bed are found on the western side of the Cincinnati geanticline, along the Ohio river and thence northward to Laurel, Indiana.

In the neighborhood of Madison,* Indiana, a layer of massive corals, often of large size, has been adopted as marking the base of the Madison bed. These corals are *Columnaria alveolata*, *Columnaria halli*, and occasional specimens of *Calopoecia cribriformis*. *Tetradium minus* occurs 6 feet and, again, 7·5 feet above the massive coral layer, sometimes also 2 feet below the same. Associated with the *Tetradium*, about 6 feet above the massive coral layer, are found *Cyrtolites ornatus*, *Bellerophon capax*, *Lophospira bowdeni*, *Hormotoma gracilis*, *Ischyrodonta miseneri*, *Pterinea demissa*, and a small form of *Platystrophia* with a short hinge line. In the sandy layer immediately above are found *Rhynchotrema capax*, *Strophomena sulcata*, *Strophomena vetusta*, *Dinorthis subquadrata*, *Hebertella sinuata*, *Streptelasma rusticum*, *Streptelasma divaricans*, *Beatricea undulatum*, and a large irregular lobate species of *Heterospongia*. As a rule fossils are scarce at this horizon elsewhere in southern Indiana, with the exception of *Tetradium*, which is quite constant, and often very abundant, at this level.

The lower part of the Madison bed at Madison, 15 feet thick, consists chiefly of clayey rock weathering readily. The greater part of the remainder of the Madison bed, forming a section 32 feet thick, consists of a massive appearing more or less sandy limestone, nearly unfossiliferous, often forming abrupt vertical walls over which plunge the small streams leading to the Ohio. This more massive rock oftens shows color-banding and is the

* Indiana Geol. Surv., 21st Rept. 1897, pp. 248, 249; the lists of fossils by Dr. Cornett and Prof. Cox are in error.

banded rock of earlier surveys, formerly believed to correspond to the Medina of New York.

At the top of the Madison section is a peculiar bluish limestone weathering in a very irregular manner, and containing a considerable fauna which has been only partially studied. Among other fossils may be mentioned *Cyrtocerina madisonense*, *Orthoceras* several species, *Ischyrodonta truncata*, *Ischyrodonta* cf. *miseneri*, *Ctenodonta simulatrix*, *Rhytima* sp. near *oehana* in size, *Byssonychia* several species, *Lophospira hammelli*, *Liospira*. *Holopea hubbardi*, *Labechia ohioensis*, and various species of ostracoda.

On tracing the Madison bed northward from Madison the massive coral bed at the base does not prove to be a conspicuous feature for any great distance, nevertheless in an inconspicuous form it proves constant to its proper horizon as far north as Osgood at least. Here along the stream following the old line of the Baltimore and Ohio Southwestern railroad, about two miles northeast of the town, specimens of *Columnaria alveolata* are rather common immediately below the beds containing *Tetradium*; *Hebertella insculpta*, marking the base of the Liberty bed, occurs just below the junction of this stream with Laughery creek, with the normal vertical interval. At Versailles, however, specimens of *Columnaria alveolata* are rather rare, though some of large size are found occasionally at the proper horizon.

The *Tetradium* bed, on the contrary, often gains in importance northward. At Versailles its thickness is eight and a half feet, *Columnaria alveolata* occurring 16 inches lower down. At Osgood, it rests immediately upon the *Columnaria alveolata* bed. At the Derbyshire Falls, southwest of Laurel, the *Tetradium* bed has a vertical thickness of three and a half feet; *Hebertella insculpta*, marking the base of the Liberty bed, occurs at the proper vertical interval along the road leading from Laurel to Metamora, a short distance south of the crossing over the stream which flows from the Falls to the river.

At Madison, and southward along the Ohio river, the most characteristic part of the Madison bed is the massive sandy brownish rock, 32 feet thick, forming the upper two-thirds of the section. This phase continues northeastward from Madison across the eastern half of Jefferson county. Northwest of this line, however, toward Versailles, New Marion, Butlerville, and northward, there is a considerable change in the lithological appearance of this part of the Madison bed section. The first change is seen 5 miles north of Madison, at the crossing of Razor creek over the Graham road; here the upper part of the section equivalent to the massive brownish sandy bed is more whitish, more calcareous, and less sandy. Two miles farther

north the upper part of the Madison bed, 14 feet thick, is again massive brownish and sandy; the middle and lower part, 40 feet thick, is soft and weathers readily; *Columnaria alveolata* occurs at the base, and *Tetradium* is found 8 feet higher up. A mile and a half farther north, at Belleview, that part of the section equivalent to the upper part of the massive bed, 20 feet thick, is again more calcareous, of a more whitish or bluish color, sometimes slightly tinged with purple; it has a much more calcareous appearance, often weathers very irregularly, and evidently corresponds closely in appearance to the greater part of the Madison bed as exposed at Versailles, New Marion, Butlerville, Nebraska, and northward as far as Osgood and Zenas. This whitish or bluish calcareous form of the Madison bed is the phase most characteristic of the area in which the Clinton is absent, and in the areas immediately adjacent. In this whitish or bluish, more calcareous phase of the Madison bed, fossils, especially bryozoans, are less rare, and at some horizons, especially near the top, are even common locally. That part of the Madison section at Belleview which corresponds to the lower part of the massive division of the section at Madison, retains its brownish, more massive appearance and its practically unfossiliferous character. This part of the section, 15 feet thick, may be traced northward to Versailles, where it forms the unfossiliferous brownish shales, 9 feet thick, immediately overlying the *Tetradium* bed. These unfossiliferous shales occupy the same position along the stream following the old right of way formerly used by the Baltimore and Ohio Southwestern railroad 2 miles northeast of Osgood.

The fauna occurring at the top of the Madison bed at Madison, Indiana, including *Lophospira hammelli*, *Holopea hubbardi*, and other fossils, may be traced northward 2 miles beyond the line between Jefferson and Ripley counties. This fauna is not confined to the top of the Madison bed, but may occur at several levels, although always in the upper part of the Madison bed. Occasionally it occurs in the upper part of the layers which are equivalent to the more massive part of the Madison section, sometimes even 7 feet below their usual horizon. Farther northward, in Ripley county, in the adjacent part of Jennings county, and in the greater part of the area from which the Clinton is absent and within which pebbles are found in the Clinton, the equivalents of the *Lophospira hammelli* and *Holopea hubbardi* beds consists of sandy clays and clayey limestones containing numerous branching bryozoans and also a fair brachiopod fauna. These beds are described in the following paragraphs.

A mile and a half south of Versailles, south of the home of William Rosengarn, the sandy clay at the top of the Madison

bed, 10 feet thick, contains *Byssonychia obesa*, *Ctenodonta cingulata*, a form of *Hebertella occidentalis* in which the median depression of the brachial valve is fairly distinct toward the beak but nearly obsolete anteriorly, a variety of *Platystrophia* of medium size with the hinge line equalling or only slightly exceeding the general width of the shell, *Streptelasma rusticum*, and *Protarea vetusta*.

The same fauna, with the addition of *Schizolopha moorei* and *Streptelasma divaricans*, occurs 2 miles northwest of Versailles, where a branch of Cedar creek crosses the old road from Versailles to Osgood. It is seen also one mile northeast of Osgood south of the right of way formerly occupied by the Baltimore and Ohio Southwestern railroad, in a quarry. Here in addition to the fossils near Versailles are found *Crania scabiosa*, *Trematis millepunctata*, *Hebertella occidentalis* typical form, *Hebertella sinuata*, *Strophomena sulcata*, and *Rafinesquina alternata*. At the quarry the lower part of the section consists of limestone, which is equivalent to the upper part of the massive bed at Madison, and to the upper part of the exposure at the northern edge of Versailles. The overlying section, at least 13 feet thick, contains the fossils just enumerated. Immediately above occur layers of limestone in which are found structures which either are concretionary or are specimens of *Strephochetus* or *Girvanella*, varying between a quarter and a half inch in diameter. This layer is better exposed a quarter of a mile southwest along the same stream, nearer town. Immediately overlying this layer are thin limestones interbedded with clay, a section about 8 feet thick, containing *Hebertella sinuata*, *Platystrophia* Madison bed form, *Strophomena sulcata*, *Lophospira tropidophora*, *Protarea vetusta*, and *Streptelasma divaricans*. Several feet farther up, the top of the Madison bed consists of whitish limestone containing *Tetradium*; it evidently is the source of some of the pebbles in the Clinton limestone.

Six miles north of Osgood, a mile and a half northeast of Napoleon, the clays and thin limestones at the top of the Madison bed, exposed for a distance of at least 10 feet beneath the Clinton, contain *Rhynchotrema capax*, *Zygospira modesta*, and *Plectambonites sericea* in addition to species already mentioned. *Rafinesquina alternata* is rather abundant in the white limestone at the top of the section. *Streptelasma divaricans* is common at this horizon. *Streptelasma rusticum* is less abundant. *Hebertella* near *occidentalis* and the Madison bed form of *Platystrophia* are common here as elsewhere.

A mile north of Napoleon, a branch of Laughery creek exposes the top of the Madison bed, containing *Platystrophia acutilirita*, and a large form of *Plectambonites*, 25^{mm} in width

and strongly curved anteriorly in a geniculate manner, in addition to *Rhynchotrema capax* and other fossils,

The localities so far mentioned occur along the eastern line of outcrop of the Clinton, where the position of the fossiliferous layers, forming the top of the Madison bed, with reference to the *Tetradium* and *Columnaria* layers at its base, may be determined by following these beds along practically continues lines of exposure. The fossil lists indicate the presence in the upper part of the Madison bed of a considerable number of fossils hitherto considered as confined to lower divisions of the Richmond. There is evidently a recurrence of species usually found more abundantly in the Whitewater bed. If the existence of these species at the top of the Madison bed could not be proved by following up practically continuous exposures from Madison to the southeastern border of Ripley county, and then up the Laughery to Versailles, Osgood, and Napoleon, the occurrence of these species immediately beneath the Clinton in the Ripley island area, farther west, at a considerable distance from the continuous line of outcrop, would have been considered as indicative of the presence of one of the lower divisions of the Richmond, probably the Whitewater bed.

Five miles west of Napoleon, a mile southeast of the northwestern corner of Ripley county, on Honey creek, *Leptaena rhomboidalis*, *Strophomena vetusta*, the Richmond group form of *Cyclonema bilix*, and *Calymmene callicephala* are added to the list of species already mentioned as occurring at the top of the Madison bed. *Rafinesquina alternata* is found in the white limestone, 3 feet thick, forming the top of the Madison bed. Immediately below, *Calymmene callicephala*, *Plectambonites sericea*, and a strongly convex species of *Dalmanella*, only 13^{mm} wide, occur. The underlying beds, consisting of thin irregular limestones weathered into fragments and of greater quantities of clay, contain in addition to species already named from this locality, *Hebertella occidentalis*, *Hebertella* near *sinuata*, the Madison bed form of *Platystrophia*, *Platystrophia acutilirita*, *Strophomena sulcata*, the large strongly curved form of *Plectambonites*, *Rhynchotrema capax*, *Protarea vetusta*, *Streptelasma rusticum*, *Streptelasma divaricans*, and *Lophospira tropidophora*. The form of *Byssonychia* usually listed as *B. radiata* is present. The total thickness of the fossiliferous section here is 20 feet. This in itself would formerly have placed the reference of the Honey creek exposure to the top of the Madison bed in doubt, but the fossiliferous layers at the top of the Madison bed northeast of Osgood have an equal thickness, and the exposures at Osgood and near Napoleon carry practically the same fauna.

At Zenas, 5 miles southwest of the Honey creek exposures, the fossiliferous layers at the top of the Madison bed contain

Hebertella near *occidentalis*, and *Hebertella* near *sinuata*, *Platystrophia* Madison bed form, *Platystrophia acutilirita*, *Rafinesquina alternata*, *Ctenodonta cingulata*, *Schizolopha moorei*, and *Protarea vetusta*. Ten feet below the base of the Silurian section occurs limestone corresponding to the comparatively unfossiliferous limestone at the base of the quarry a mile northeast of Osgood, and to the top of the exposures at the north end of Versailles.

About 5 miles northwest of Zenas, and 6 miles west of the Honey creek locality, near the mouth of Painter creek, a mile and a half southeast of Westport, the top of the Ordovician, exposed in a vertical section 15 feet thick, contains the following fossils, which have been listed also from other localities farther east: *Dalmanella* small species with very convex brachial valves, *Hebertella* near *occidentalis*, *Hebertella sinuata*, Madison bed form of *Platystrophia*, *Platystrophia acutilirita*, *Leptaena rhomboidalis*, *Strophomena sulcata*, *Strophomena vetusta*, large form of *Plectambonites* strongly deflexed anteriorly, *Rhynchotrema capax*, *Trematis millepunctata*, *Protarea vetusta*, *Streptelasma rusticum*, and *Streptelasma divaricans*. *Dinorthis subquadrata*, not noted so far at this horizon, occurs also.

From Versailles the top of the Madison bed is exposed almost continuously along Big Graham creek as far as Benville. At New Marion the fossiliferous clayey beds overlying more solid limestones produce a section easily recognized as equivalent lithologically and faunally to that at the top of the Madison bed at Versailles. Four miles north of Benville, a mile and a half south of Nebraska, the banks of Otter creek expose a considerable section of Richmond rocks, about 60 feet thick, all of which is placed in the Madison bed, being regarded as a nearly complete section of the Madison bed at this locality. The fossils include the Madison bed form of *Platystrophia*, *Hebertella* near *sinuata*, and *Streptelasma divaricans*. At some horizons bryozoans are rather common, and their study may accomplish much in the future in confirming or combating the views here expressed, since the bryozoans are better horizon markers as a rule in the Cincinnati formations than the brachiopoda. In fact, the observations here recorded are direct evidence of the limited value of brachiopoda as horizon markers since most of the species here listed for the first time from the Madison bed have long been known from lower horizons in the Richmond.

Unconformity between Madison and Niagaran beds comparatively small.—The thickness of the Madison bed varies in an irregular manner in Indiana and western Kentucky, but in general there is a decrease in thickness on passing from Madison southward toward central Kentucky. In the opposite

direction, on passing from Kentucky toward Indiana, there is an increase of thickness and the observations so far made indicate that this increase continues northward from Madison toward the areas in the central part of Ripley and Jennings counties, in which the Clinton is absent. The two or three feet of fossiliferous strata at the top of the Madison bed at Madison appear to be the attenuated representatives of the much thicker fossiliferous beds at the top of the Madison bed in the central part of Ripley and Jennings counties. The Silurian, therefore, instead of resting upon lower beds of Richmond age in the region in which the Clinton is absent, actually rests on beds representing the latest deposits of Madison age so far studied. The small degree of unconformity between the top of the Ordovician and the base of the Silurian in the areas of Indiana, Ohio, and northern Kentucky, so far under investigation, is a most striking feature, considering the great lapse of time intervening between their disposition, as indicated by the great difference of their faunas.

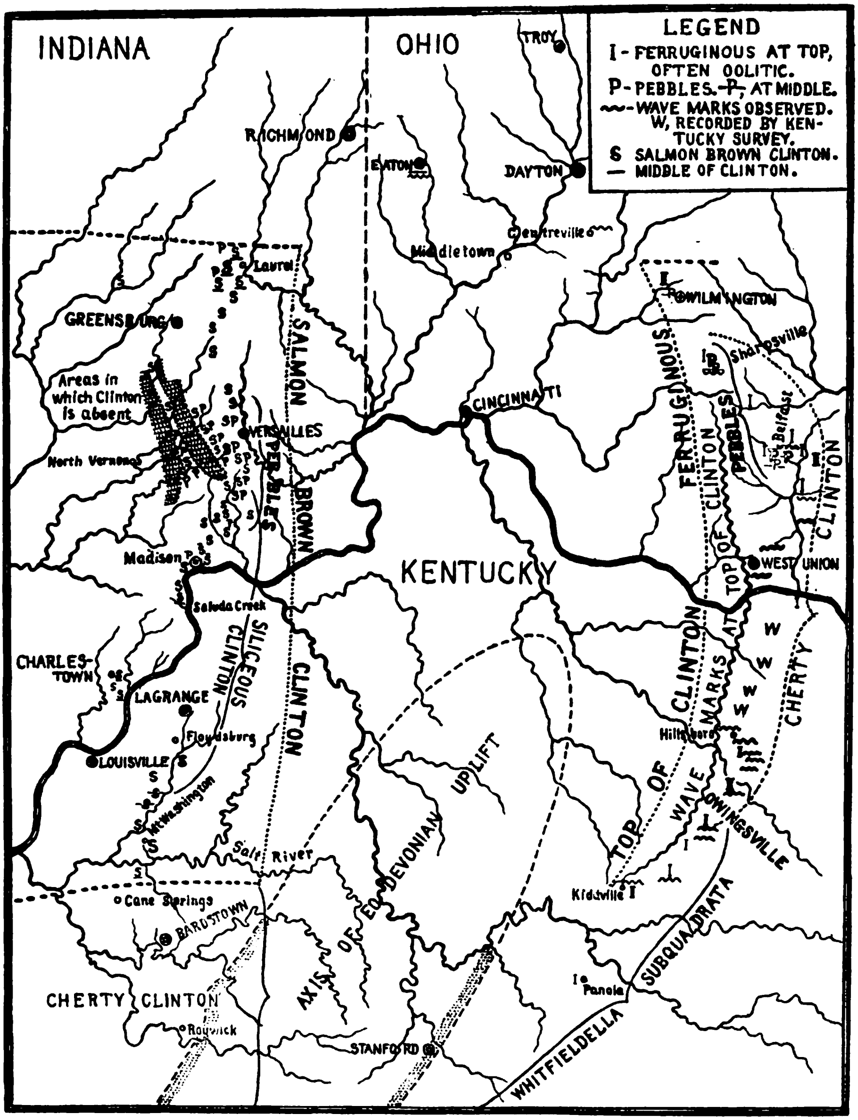
The *Lophospira hammelli–Holopea hubbardi* fauna may be traced from the southern margin of Ripley county to Floydsburg, in Kentucky, about 13 miles southeast of Charlestown landing. The fauna appears to be a depauperate one, a number of genera being represented by species of comparatively small size.

Parallelism of certain features shown by Clinton on opposite sides of the geanticline.—Along the same line of exposures, between the northwestern corner of Switzerland county and Lagrange, in Kentucky, the Clinton is usually quite thin, has a light red or pink instead of a salmon-brown color, and lithologically appears to be a dense siliceous limestone instead of a detrital limestone. Salmon-brown detrital phases are seen along this line but are less common. The area in which the siliceous phases of the Clinton are common is indicated on the accompanying map. Farther south, toward Mount Washington and for a short distance south of Salt river, in Kentucky, the salmon-brown, detrital phases of the Clinton are seen again. Northward, the salmon-brown phases of the Clinton extend as far as Laurel, Indiana.

The salmon-brown color of the Clinton in Indiana and western Kentucky appears to be due to the presence in very small quantity of some iron compound, sufficient to stain the calcite, but not visible to the eye, even under a microscope, as a substance distinct from the calcite. In Ohio and Kentucky, east of the Cincinnati geanticline, ferruginous layers occur at the top of the Clinton at many localities * within an area which

*Ohio Geol. Surv., iii, p. 442, 1878. Ohio Geol. Surv., Rept. for 1870, pp. 268, 269. Kentucky Geol. Surv., Rept. on Bath county, by W. N. Linney, p. 18, 1886. On the Clinton oolitic iron ores, this Journal, xli, 28, 1891.

has approximately the same northward and southward extension as the salmon-brown Clinton west of the geanticline. The



Map showing similar distribution of conglomeratic, ferruginous, and siliceous phases of the Clinton on opposite sides of the Cincinnati geanticline.

extent of this area is indicated on this plate. At the Rose Run Mining Company quarries, 4 miles east of Owingsville, the

ferruginous layers have a thickness of 3 feet and are sent to the iron furnaces along the Ohio river. The rock was originally a detrital limestone, more or less oolitic, but has in the course of time been replaced in part by a red iron ore which often preserves the structure of the fragments and of the more complete specimens of fossils, indicating the source of the material to which the rock owes its original composition. The rock was formerly quarried for use in smelters also at other localities in Kentucky and Ohio, but the development of iron industries elsewhere, in other states, on a much larger scale, has led to the abandonment of these workings in the Clinton of Kentucky and Ohio at all localities except at Owingsville.

Pebbles are found in the Clinton of Ohio at other localities* than the locality first described by Professor Orton. They are abundant at several horizons in the Clinton near Sharpsville. The area within which they are fairly common is indicated on the accompanying map. It is interesting to notice that this area is located directly east of the area in Indiana where pebbles are so common. At some localities in Ohio the pebbles are of much larger size than those usually found in Indiana; at one locality 2 miles east of Belfast, pebbles 4 to 8 inches in length are common, and quite a number attain a length of 12 inches. They are always strongly rounded.

Wave-marks are characteristic of the top of the Clinton over a wide area in Kentucky and Ohio. The extent of this territory is indicated on the accompanying map; it is almost coincident with the extent of the area containing ferruginous deposits.

In case the Cincinnati geanticline was already sufficiently developed in Clinton times to form a barrier in southern Ohio, Indiana, and adjacent Kentucky, the opposition of conglomeratic and salmon-brown deposits of Clinton age, west of the geanticline, to conglomeratic, ferruginous, and wave-marked deposits east of the geanticline may have little connection. In case this barrier did not exist, the observations so far made are in favor of a gradual diminution in thickness of the Clinton across the northern part of the field. They do not exclude the possibility of the former presence of the Clinton, thinning westward, even across the northern extremity of Kentucky. In this case the same cause may have been operative in both territories, east and west of the geanticline. The evidence of wave and current action is much stronger in the area east of the geanticline than westward. It is impossible to determine from the evidence at hand whether the few feet of Clinton strata west of the geanticline, in the region nearest the areas from which the Clinton is absent, are to be regarded as equiva-

*Journ. Geol., iii, pp. 16–30.

lent to the upper part of the Clinton east of the geanticline or as practically equivalent to the entire eastern section. So far no great difference has been noticed in the faunas in the upper and lower parts of the Clinton, east of the geanticline.

Additional notes on the development of the Cincinnati geanticline.—The pre-Meso-Devonic origin of the Cincinnati geanticline is shown best in Kentucky and Tennessee. Along the crest of the geanticline Devonian rocks rest on Ordovician formations, but both east and west of the crest the Devonian rests on successively younger beds of the Niagaran. The thinning out of the Louisville bed diagonally up the western flank of the geanticline from at least 60 feet at Louisville to nothing at Greensburg, and a similar thinning from the eastern parts of Bartholomew and Shelby counties eastward toward Greensburg, suggest similar conditions farther northward, in Indiana. At Greensburg,* according to Mr. J. A. Price, the sandy limestone of the Devonian rests directly upon the upper layers of the Laurel bed, even the Waldron bed being absent. The pre-Meso-Devonic age of the geanticline is indicated also in southern Ohio,† where, according to Professor Orton, neo-Devonian black slates or shales rest in succession on Niagaran, Cayugan, and Meso-Devonic limestones on proceeding from Highland county across Ross toward Franklin and Delaware counties. The presence of unconformable contacts between the Niagaran and Devonian in northern Indiana, at Delphi, Georgetown, and Kentland,‡ has been shown by Dr. E. M. Kindle. The evidence at hand, however, does not demonstrate the presence of the Indiana branch of the geanticline in pre-Devonic times.

The most interesting contribution of Dr. Kindle to the pre-Meso-Devonic geology of northern Indiana is the demonstration of the presence of strongly quaquaversal dips affecting Silurian rocks previous to the deposition of the Devonian. At some localities these dips suggested the presence of small domes. Quaquaversal dips, although usually of a much less pronounced character, are shown by Silurian strata also in central and southern Kentucky, and along the western flank of the geanticline in Tennessee. In fact, all the evidence so far accumulated indicates that while the Cincinnati geanticline in general shows a very simple structure, locally it may show strongly quaquaversal dips connected with subsidiary folds whose axes may be very divergent from the main axis of the geanticline. Owing to the low inclination of the rocks over the greater part of the area, these subsidiary folds attract much more attention than they would in a more highly inclined series of rocks.

* Indiana Geol. Surv., 24th Rept., pp. 87-90.
† Ohio Geol. Surv., Rept. for 1870, pp. 285-287.
‡ This Journal, vol. xv, p. 459, 1903.

Quaquaversal dips may have existed even before the deposition of the Niagaran. The variations in thickness of the Clinton in some parts of Kentucky and Tennessee are of an irregular character and can not be correlated in such a manner as to demonstrate the presence of the Cincinnati geanticline in pre-Niagaran times. The presence of wave-marks and pebbles in the Clinton of Ohio, Indiana, and northern Kentucky may have been connected with the existence in early Silurian times of very low irregular elevations of land of comparatively small extent in a very shallow expanse of sea covering wider areas. Similar wave-marks and pebbles are found at various elevations in the Richmond group in southwestern Ohio,* northern Kentucky, and southeastern Indiana.

The formation of the Cincinnati geanticline probably began with a general elevation of the sea bottom over wide areas, producing shallow waters. The irregular distribution at different levels of wave-marks and pebbles in rocks of Richmond age show that during late Ordovician times the waters were locally sufficiently shallow to bring the sea bottom within the range of action of waves, some parts being probably exposed to the air, at least at low tide. Along the western ranges of the Alleghanies there may have been a wide expanse of dry land, since the Richmond is absent eastward. Later there was a depression of the area eastward permitting the deposition there of the neo-Niagaran, but no deposits of this kind are known in the region of the Cincinnati geanticline, although their existence has been inferred in eastern and northern Ohio, below the cover of later rocks, from the records of drillers.

During early Niagaran times the depression appears to have progressed sufficiently to permit of the deposit over wide areas of the Clinton. There is no evidence, however, that the Clinton ever reached the western half of Indiana and the adjacent part of Kentucky. During the Clinton irregular shallow water conditions prevailed in certain areas. The Osgood clays may formerly have extended across the region of the present Cincinnati geanticline. The moderate quaquaversal dips of the earlier part of the Niagaran were followed in some areas by the stronger quaquaversal dips of the later Silurian. Just when the changes in level involved resulted in the production of the initial stages of the axis of the present Cincinnati geanticline is unknown, but it probably preceded Devonian times since in the Meso-Devonian the Cincinnati geanticline had attained considerable development.

While the origin of the Cincinnati geanticline in pre-Meso-Devonic times can be demonstrated, it owes its present proportions chiefly to later orogenic processes. In Ohio, the labors of Professor Orton have demonstrated to what a remarkable extent the present development of the geanticline was depend-

* Journ. Geol., 1895, pp. 6, 7, 9-11.

ent upon post-Meso-Devonic folding. His sections from Bryan to Sandusky,* and from Bryan to Bucyrus show this clearly, and similar sections collated from his notes on the well records of more southern areas indicate to what a large extent the geanticline owes its importance to post-Meso-Devonic folding. The strong eastward dip of the neo-Devonic black shales and of the Waverly indicate that a great part of this folding was probably of post-Mississippian age. Similar facts are observed also along the Ohio river, west of the crest of the geanticline, near Louisville,† where it is evident that the rapid westward dips affecting the neo-Devonic black shale and the Mississippian strata are largely instrumental in giving prominence to the geanticline. Similar facts are observed also in Kentucky and Tennessee. The elevation of the Cincinnati geanticline was therefore a process, probably more or less interrupted, but continuing through long geological ages, the greater part of the development of this fold having taken place in post-Devonian, and probably in post-Mississippian times.

Approximate relationship of Clinton and Osgood Faunas of Indiana to the lower Niagaran Faunas of New York.

The Osgood bed introduces the typical Niagaran fauna. Here are found the first species of *Gomphocystites*, *Holocystites*, *Stephanocrinus*, *Pisocrinus*, and *Lecanocrinus;* here are found the first specimens of *Pentamerus oblongus*, *Rhynchotreta cuneata americana*, typical *Camarotoechia neglecta*, *C. indianensis*, *Atrypa reticularis*, *Spirifer radiatus*, *Sp. eudora*, *Sp. niagarensis*, *Cyrtea exporrecta*, *C. myrtea*, *Nucleospira pisiformis*, *Whitfieldella cylindrica*, *Atrypa calvani*, *Orthoceras amycus*, *O. medullare*, and *Dalmanites limulurus*.

The Clinton of Ohio, Indiana, and Kentucky contains a fauna so different from that of New York and other eastern localities that the existence of some sort of a barrier between these two areas has been suggested. The attempt formerly to identify western Clinton species by means of the plates in the second volume on the paleontology of New York has resulted in various errors not yet corrected. It is certain that the species identified as *Strophonella patenta* from the Clinton of Ohio is distinct from the type species described from New York and the name *Strophonella daytonensis* is here suggested for the same. The identification of *Phacops trisulcatus* rests upon very unsatisfactory grounds. Such names as *Cornulites distans*, *Orthoceras clavatum*, *O. virgulatum*, *Conularia niagarensis*, and *Murchisonia subulata*, can have little value

* Ohio Geol. Surv., vi, 1888, pp. 48, 134, 183, 305. Am. Geol. 1891, pp. 105–108.

† Indiana Geol. Surv., 25th Rept., map, p. 349; Silver Creek Hydraulic limestone, by C. E. Siebenthal; also 26th Rept., 1903, maps, pp. 235, 261; Geological section across southern Indiana, by J. F. Newsom.

until much better representatives of the type species are secured. *Sphaerexochus pisum* is a species of *Deiphon* and is closely related to *D. forbesi*. Representatives of genera more abundantly represented in the Ordovician occur in the Clinton, such as *Platystrophia daytonensis*, *Pl. reversata*, *Hebertella fausta*, *H. daytonensis*, *Cyclonema daytonensis*. A form of *Plectambonites* allied to *Pl. sericea* is the only species passing from the Ordovician into the Clinton with little change; the more distinct form, *Pl. transversalis*, however, is much more common. The identification of the lowest Silurian bed in the area of the Cincinnati geanticline as Clinton does not rest so much upon the identity of faunas at the two localities as upon the presence of a few species which are identical, a few which are closely allied, the general absence of species which may be regarded as most typical of the Rochester shale of New York, and a general facies which suggests that the western fauna represents a somewhat similar stage in development.

In New York, some of the species, which in the area of the Cincinnati geanticline are not found beneath the Osgood bed, occur in the lenses at the top of the Clinton; some of them occur even in the upper beds of the Clinton. As far as may be determined from the evidence at hand, the Osgood bed contains a part of the fauna of the lenses at the top of the Clinton and of the lower half of the Rochester shales in New York, a part of this fauna beginning at the top of the Clinton in that state; while the Clinton of Ohio, Indiana, and Kentucky appears to have attained the stage of development equivalent to that of the Clinton of New York, below the lenses, but does not contain such species as *Pentamerus oblongus*, *Atrypa reticularis*, *Spirifer radiatus*, *Sp. niagarensis*, which in the west begin their existence in the Osgood bed. The faunal elements of the Clinton in the two areas are different and a more exact comparison is at present impossible.

Lists of Niagaran Fossils.

The best lists of the fossils of the various subdivisions of the Cincinnatian strata in Ohio, Indiana, and adjacent Kentucky are those published by Mr. J. M. Nickles in the Journal of the Cincinnati Society of Natural History, volume xx, No. 2, 1902.

A list of the fossils identified from the Clinton of Indiana was published in "Silurian and Devonian limestones of Tennessee and Kentucky," a Bulletin of the Geological Society of America, in 1901, on pages 438–441.

Osgood Fossils.

In the following list the names of the localities Osgood, New Marion, and Big Creek are indicated by the letters O, N, and B following immediately after the name of the species. Unless

otherwise recorded, the crinoids and cystids are from Big Creek :

Receptaculites ———, B.
Ceramopora imbricata. O,N,B.
Mesotrypa milleri, O.
Idiotrypa parasitica, O.
Callopora elegantula, O.
Pachydictya crassa, O.
Duncanella borealis, O,N.
Favosites forbesi, O,B.
Favosites cristatus, B.
Striatopora flexuosa, O.
Striatopora sessile on crinoid stems, O.
Thecia major, O.
Plasmopora ———, O.
Allocystites hammelli, Rikers Ridge.
Caryocrinus ellipticus, O.
Caryocrinus indianensis.
Caryocrinus hammelli.
Caryocrinus ornatus.
Gomphocystites indianensis.
Holocystites abnormis, Madison ?
adipatus.
affinis.
amplus, Big Creek ?
asper.
brauni.
benedicti.
bacculus.
canneus.
colletti.
commodus.
cylindricus.
dyeri, Osgood.
elegans.
faberi.
globosus.
gorbyi.
gyrinus.
hammelli.
indianensis.
madisonensis.
ornatissimus.
ornatus.
ovatus, Madison ?
papulosus.
parvulus.
parvus.
perlongus, O.
plenus.
rotundus, O.
scitulus.
spangleri.
spaeroidalis.
splendens.
subglobosus, Big Creek ?
subovatus.
subrotundus, O.
tumidus.
turbinatus, O.
ventricosus, O.
wetherbyi, O.
wykoffi.
Pisocrinus gemmiformis, O,N,B, Nebraska.
Stephanocrinus cornetti, B, Rikers Ridge.
deformis.
elongatus, O,B.
hammelli, O.
obpyramidalis.
osgoodensis, O.
quinquepartitus.
Orthis flabellites, O,N,B, Nebraska.
Platystrophia biforata, Nebraska.
Dalmanella elegantula, O,N.
Rhipidomella hybrida, O,N, Nebraska.
Leptaena rhomboidalis. N,B.
Plectambonites transversalis, O,N,B, Nebraska.
Rhynchotreta cuneata-americana, O.
Camarotoechia neglecta, N,B.
Camarotoechia indianensis, O.
Atrypa reticularis, O.N,B.
Spirifer radiatus, N,B.
Spirifer eudora, N.
Spirifer niagarensis, N,B.
Cyrtia exporrecta, N.B.
Cyrtia myrtea (meta !), N.
Nucleospira pisiformis, N.
Whitfieldella cylindrica, N.
Whitfieldella quadrangularis, B.
Atrypa calvani, B.
Diaphorostoma niagarense, O,N,B.
Orthoceras simulator, B.
Orthoceras amycus, O,B.
Orthoceras medullare, B.
Calymmene nasuta, O,B.
Dalmanites limulurus, O.
Illaenus ———, O,B.

In Ohio Pentamerus oblongus occurs in the Dayton limestone, equivalent to the base of the Osgood bed.

Laurel Fossils.

Unless otherwise stated, the fossils are from St. Paul.

Amplexus	cinctutus, Miller.
Favosites	spongilla, Rominger.
Streptelasma	spongiaxis, Rominger.
Striatopora	gorbyi, Miller.

Plasmopora	follis, Milne-Edwards.
Plasmopora	scita ? Milne-Edwards.
Aethocystites	sculptus, Miller.
Allocrinus	benedicti, Miller.
Calceocrinus	indianensis, Miller.
Callicrinus	beachleri, Wachsmuth + Springer.
Caryocrinus	ellipticus, Miller + Gurley.
Cyclicocrinus	canaliculatus, Miller.
Cyclicocrinus ?	indianensis, Miller + Gurley.
Cyphocrinus	gorbyi, Miller.
Emperocrinus	indianensis, Miller + Gurley.
Gazacrinus	inornatus, Miller.
Holocystites	pustulosus, Miller: a few miles from Waldron, Indiana, some distance below the range of Waldron beds.
Hyptiocrinus	typus, Wachsmuth + Springer.
Idiocrinus	elongatus, Wachsmuth + Springer.
Idiocrinus	ventricosus, Wachsmuth + Springer.
Indianocrinus	punctatus, Miller + Gurley.
Macrostylocrinus	indianensis, Miller + Gurley.
Mariacrinus	aureatus, Miller.
Mariacrinus	granulosus, Miller.
Melocrinus	equalis, Miller.
Melocrinus	oblongus, Wachsmuth + Springer.
Melocrinus	parvus, Wachsmuth + Springer.
Pisocrinus	baccula, Miller + Gurley.
Pisocrinus	globosus, Ringueberg.
Saccocrinus	benedicti, Miller.
Saccocrinus	howardi, Miller.
Saccocrinus	umbrosus, Miller + Gurley.
Stribalocystites	gorbyi, Miller.
Stribalocystites	tumidus, Miller.
Stribalocystites	spheroidalis, Miller + Gurley.
Zophocrinus	howardi, Miller.
Spirifer	radiatus, Sowerby. From Madison.
Cyrtoceras	howardi, Miller.
Cyrtoceras	indianense, Miller.
Orthoceras	annulatum,
Orthoceras	imbricatum,
Orthoceras	subcancellatum,
Cyrtoceras	elrodi, White.
Lichas	byrnesanus, Miller + Gurley. From neighborhood of Madison.
Lichas	hanoverensis. Miller + Gurley. From Hanover.

The fauna of the Waldron bed was described by Hall in the eleventh annual report of the Indiana Geological Survey, this being a republication of various papers in the Transactions of the Albany Institute and the New York State Museum Reports.

The brachiopod and gasteropod fauna of the Louisville bed was described by Henry Nettelroth in Kentucky Fossil Shells of the Silurian and Devonian Rocks, 1889, a publication of the Kentucky Geological Survey. The corals of the Louisville bed were figured by W. J. Davis, in Kentucky Fossil Corals of the Silurian and Devonian Rocks, 1885. In these publications all fossils cited from Silurian rocks, with the possible exception of *Zaphrentis patula*, *Z. socialis*, and *Z. patens*, come from the Louisville bed.

Dayton, Ohio.

ART. XXXVII.—*A Crystallographic Study of Millerite*; by CHARLES PALACHE and H. O. WOOD.

THE crystallographic character of millerite was first defined by Miller in 1835 in a paper* interesting historically as containing the first presentation of his index system of notation. He determined the forms *o*, (0001), *b*, (10$\bar{1}$0), *k*, (21$\bar{3}$0), *e*, (01$\bar{1}$2), *r*, (10$\bar{1}$1), $r_{,}$, (01$\bar{1}$1) and *v*, (50$\bar{5}$2) on crystals without natural terminations, but which had been broken across. And on a single terminated crystal with dull faces, he found the form *t*, (03$\bar{3}$1) by contact measurement. The angle $o \wedge r = 20° 50'$ was the average of several readings, and led to the axial ratio a : c = 1 : 0·3295 which is at present accepted. In the lack of details as to faces and measurements, we are forced to conclude that he, at that time, considered five kinds of cleavage present, parallel to *o*, *e*, *r*, $r_{,}$, and *v*. In his Mineralogy† the matter is presented somewhat differently. The prism *a*, (11$\bar{2}$0) is added, and instead of *v*, (50$\bar{5}$2), is given $e_{,}$, (10$\bar{1}$2), without explanation. He also states that possibly the appearance of cleavage on both positive and negative rhombohedrons, *r* and $r_{,}$ and *e* and $e_{,}$, is due to concealed twinning on the vertical axis. The occurrence of the rhombohedron *v*, (50$\bar{5}$2), is therefore left in doubt, and cleavage parallel to the base and to the two rhombohedrons *r* and *e* is indicated.

In 1892, Laspeyres‡ described beyrichite and paramorphs of millerite after beyrichite. He concludes that all millerite is derived from beyrichite, and that for the crystals of both minerals examined, the crystallographic characters are identical. The forms observed were *b*, (10$\bar{1}$0), *a*, (11$\bar{2}$0), *i*, (41$\bar{5}$0), *r*, (10$\bar{1}$1) and *e*, (01$\bar{1}$2); the two last both as cleavages and as dull terminal faces, and each in apparently positive and negative positions through twinning about the vertical axis. The axial ratio a : c = 1 : 0·3277 was derived from measurement of the cleavage rhombohedron.

The form *i*, (41$\bar{5}$0), is based on poor measurements, the average differing by more than a degree from the calculated value, and therefore is to be regarded as very doubtful.

In 1893, the same author in a paper§ on the various nickel deposits of the Rhine, describes various occurrences of millerite. On specimens from two localities, terminated but not measurable crystals were observed, on which *c*, (0001) and *r*, (10$\bar{1}$1) were present together with the ordinary prism forms.

The list of forms known on millerite up to the present time

* Phil. Mag., vi, 104, 1835. † Phillips Mineralogy, 163, 1852.
‡ Zeitschr. f. Kryst., xx, 535, 1892.
§ Das Vorkommen und die Verbreitung des Nickels im Rheinischen Schiefergebirge. Verh. Nat.-hist. Ver. Rheinl., 1, 142, 1893.

reads then as follows: *b*, $(10\bar{1}0)$, *a*, $(11\bar{2}0)$, *k*, $(21\bar{3}0)$, *c*, (0001), *e*, $(01\bar{1}2)$, *r*, $(10\bar{1}1)$, and doubtful *i*, $(41\bar{5}0)$, *v*, $(50\bar{5}2)$ and *t*, $(03\bar{3}1)$. Cleavage parallel to *r* and *e* is established.

In the Mineral Cabinet of Harvard University is a suite of specimens derived from the collection of Prof. J. D. Whitney, illustrating the occurrence of millerite, and its associated minerals, at the old Nickel Mine at Orford, Province of Quebec. The beauty, perfection and unusual size of these crystals of millerite led to their study, and examination of the literature revealed the fact that no detailed description of this occurrence existed. Such a description is here presented, since the study of this material has added largely to our knowledge of the crystallography of millerite.

The nickel deposit occurs on the east side of Brompton Lake in Orford Township, Province of Quebec. It consists, as may be gathered from scattered notes in the Canadian Survey Reports, of a large vein chiefly composed of granular white calcite which traverses serpentine. Mingled with the calcite and especially abundant near the vein walls are considerable masses of a bright green chrome-garnet in granular aggregates, and of a light colored diopside, both granular and in long stout crystals. Millerite in grains and prisms is scattered irregularly through the vein matter. The deposit has long been known, and it seems to have been worked for a short time in the seventies, but was abandoned soon, the nickel content of the vein material, less than one per cent, having been too small to pay for extracting.

The specimens in hand consist chiefly of chrome-garnet, partly in granular masses, partly in aggregates of minute individual crystals held together by a cement of calcite, the removal of which with acid causes the mass to crumble. In the latter case, and indeed wherever the garnet is in contact with the calcite, it is in sharp crystals, with the dodecahedron as the dominant form. On a few crystals the dodecahedron edges were truncated by planes, which on measurement proved to be those of two hexoctahedrons, (358) and (459), the latter new to garnet. The faces were extremely narrow and the reflections poor, hence the considerable variations in the position of the faces.

Symbol.		Observed angles (av.).		No. of faces.	Calculated angles.	
Miller.	G_1.	ϕ	ρ		ϕ	ρ
(358)	$\frac{3}{8}$ $\frac{5}{8}$	32° 12′	35° 37′	6	30° 58′	36° 05′
(385)	$\frac{3}{5}$ $\frac{8}{5}$	21° 00′	60° 08′	5	20° 33′	59° 40′
(583)	$\frac{5}{3}$ $\frac{8}{3}$	31° 21′	71° 42′	5	32° 00′	72° 21′
(459)	$\frac{4}{9}$ $\frac{5}{9}$	39° 16′	35° 26′	6	38° 39′	35° 26′
(495)	$\frac{4}{5}$ $\frac{9}{5}$	23° 36′	62° 43′	5	23° 58′	63° 05′
(594)	$\frac{5}{4}$ $\frac{9}{4}$	28° 46′	68° 17′	5	29° 03′	68° 46′

The garnet is green in color, varying from a yellowish tone in massive specimens to a deep emerald-green in the sparkling transparent crystals.

The following analysis by T. Sterry Hunt is taken from Dawson, Geology of Canada, p. 497.

	I.	II.
SiO_2	36·65	
Al_2O_3	17·50	
Cr_2O_3	6·20	6·93
FeO	4·97	4·80
CaO	33·20	33·29
MgO	0·81	
Volatile	0·30	
Total	99·63	

The analysis shows that the garnet is ouvarovite, but with a very small proportion of chromium.

Specks of chromite are embedded in the garnet, in places quite abundantly.

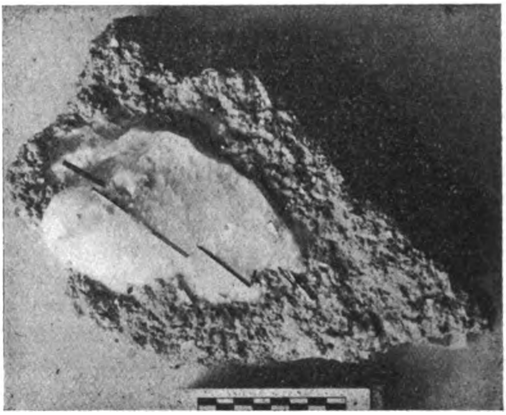
The pyroxene is yellow-gray or pale green, and is either in isolated crystals embedded in calcite, in granular masses consisting almost wholly of this mineral, or in minute crystals implanted on the surface of garnet aggregates. The crystals are prismatic and are often large, up to six or more inches in length. The pinacoids *a*, (100) and *b*, (010) are dominant, and narrow faces of the prisms *m*, (110) and *i*, (130) are always present. These forms always have smooth and brilliant faces; the terminating planes, on the contrary, are always dull and measurements could be obtained only with great difficulty. The forms *p*, ($\bar{1}01$) and *u*, (111) are always present and occasionally minute faces of *c*, (001), *s*, ($\bar{1}11$), and several other pyramids not corresponding to established pyroxene forms were noticed. Twins on the common pyroxene law, (100) the twinning plane, are common. No analysis of this material could be discovered.

The calcite vein-filling is snow-white and very coarsely granular, individual cleavage rhombs up to three inches across being at hand. It is characterized by an extreme development of pressure-twinning parallel to *e*, ($01\bar{1}2$), so that a parting parallel to the negative rhombohedron with smooth reflecting surfaces scarcely inferior to those of the cleavage, is often obtained. The occurrence of this twinning-parting in the calcite is especially noteworthy, since this identical structure is also developed in the millerite, as will be shown presently.

Millerite occurs scattered through the massive garnet, more abundantly at the boundary between garnet or pyroxene and calcite, and finally wholly embedded in calcite. The aggre-

gates of garnet, pyroxene, calcite and millerite are such that no sequence of formation can be recognized, all appearing rather to have crystallized together. When in the massive garnet the millerite is in grains of small size. On contact surfaces as developed by removal of calcite with acid, the millerite is either in short stout prisms loosely implanted on the garnet and projecting into the calcite with developed terminal planes; or it is in long and relatively slender striated prisms, which lie parallel to the garnet surface and adhere to it closely, being bent, twisted and contorted in extraordinary fashion as though, after formation, the crystals had been pressed down

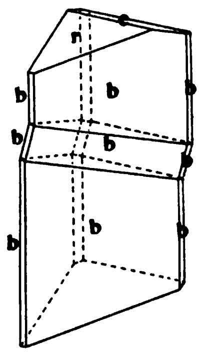
1



to fit all the irregularities of the uneven underlying surface. Their appearance is unique; and no explanation of their probable mode of formation has occurred to us. So soon as the millerite passes from the immediate contact zone, and is embedded in calcite, the crystals are free from these extreme dislocations; the long prisms are sometimes warped and knicked by pressure-twinning, but entirely lose the crushed appearance as described above. Crystals may be seen crushed and twisted where they lie prone, but which pass into the calcite and become immediately relatively straight and plane-surfaced. The millerite crystals in the calcite reach dimensions quite unusual for this mineral. Prisms two millimeters in diameter and four centimeters long are present among our specimens. They are said to reach a length of eight centimeters or more (three inches). These prisms are generally sharply trigonal in outline, the three faces bright and polished

and the angles rounded and striated. No terminated crystals of this type were found, all showing terminal planes of cleavage only. A striking and hitherto unknown character of the mineral was first seen and interpreted on one of the triangular cleavage fragments shown in fig. 2. This crystal consists of three segments, the upper and lower ones parallel, the intermediate portion in twin position to the other two, a face of the form *e*, $(01\bar{1}2)$, being the twinning plane. $10\bar{1}1 \wedge \underline{10\bar{1}0}$ (twin), measured 21° 23′½, calculated 21° 25′. The form of the twin suggested that it might be due to the presence of a gliding plane and produced by pressure; and experiment soon showed this to be the case. A crystal held firmly and subjected to shearing stress can be offset readily. The same

2



result may be obtained by placing the crystal on a yielding support, and pressing upon it transversely with a knife-edge, in which case a fine lamella is thrown into twin position. The gliding takes place with equal ease, of course, parallel to each of the three rhombohedron planes. With very slender crystals it is difficult to produce the twinning, the pressure breaking the brittle substance to pieces, and this probably accounts for the failure to recognize this remarkable property of millerite hitherto. Careful tests on millerite crystals from a number of localities were uniformly successful, and showed it to be a general property of the mineral. In view of the ease with which this gliding twinning can be obtained, and of the striking effect produced, it seems that millerite should take equal rank with calcite as an illustration of this interesting phenomenon.

Highly perfect cleavage is present parallel to the unit rhombohedron, *r*, $(10\bar{1}1)$, and also to the negative rhombohe-

dron, *e*, $(01\bar{1}2)$, the latter identical with the gliding plane. No difference in the quality of the two cleavages can be detected, and planes of both are generally produced when a crystal is broken. No indication of a cleavage parallel to a prism, such as Laspeyres found in millerite derived from beyrichite, was observed.

The Orford millerite is characterized by brilliant metallic luster, and a pale brass-yellow color which is quite constant on all planes and surfaces of the mineral. Laspeyres' conclusion mentioned above, that all millerite is derived from beyrichite, a conclusion based largely on an observed color change, finds absolutely no support in this occurrence.

No analysis of the millerite was made. Careful qualitative tests for copper and cobalt gave only negative results, and it is probably very nearly pure nickel sulphide.

Crystallography.

A number of crystals showing natural terminal planes were obtained from several of the specimens by removal of calcite with hydrochloric acid. In the majority of cases, the crystals were attached to the matrix by an end and thus showed but a single termination; two or three crystals of poor quality were found which were attached by prism faces and thus showed both terminations. These crystals were in all cases small, from 2 to 5^{mm} in length, and from $0{\cdot}1^{mm}$ to 1^{mm} in diameter. In habit they vary from slender prisms to short stubby crystals of diameter equal to or greater than their length.

In all thirty-two crystals were measured. Of these twenty-eight were measured completely in the two-circle goniometer. Four were measured for special angles.

From the data obtained in measurement, the following forms were established, those marked with a star being new: *b*, $(10\bar{1}0)$, *a*, $(11\bar{2}0)$, *k*, $(21\bar{3}0)$, *d*, $(72\bar{9}0^*)$, *r*, $(10\bar{1}1)$, *v*, $(50\bar{5}2)$, *p*, $(02\bar{2}1^*)$, *s*, $(21\bar{3}1^*)$ and *u*, $(\bar{4}\bar{1}53^*)$. Doubtful values for the following forms were found. These need confirmation for their establishment. *i*, $(41\bar{5}0)$, *f*, $(9{\cdot}4{\cdot}\overline{13}{\cdot}0^*)$, *g*, $(31{\cdot}13{\cdot}\overline{44}{\cdot}0^*)$, *t*, $(03\bar{3}1)$, *h*, $(30\bar{3}1^*)$, *x*, $(40\bar{4}1^*)$, *j*, $(50\bar{5}1^*)$, *l*, $(09\bar{9}1^*)$, *m*, $(0{\cdot}18{\cdot}\overline{18}{\cdot}1^*)$, *n*, $(52\bar{7}6^*)$, *o*, $(7{\cdot}4{\cdot}\overline{11}{\cdot}9^*)$, *q*, $(51\bar{7}4^*)$, and *w*, $(42\bar{6}5^*)$. The only forms satisfactorily established which we did not find on the Orford mineral are the base *c*, (0001), which was observed by both Miller and Laspeyres, and the rhombohedron *e*, $(01\bar{1}2)$ observed by the latter.

Measurements were obtained from the dominant rhombohedrons from which a satisfactory axial ratio could be calculated.

For r, $(10\bar{1}1)$

10 readings,	very	good signals,	average	value	of	$\rho=20°\ 43'\cdot 4$
11	"	good	"	"	"	$\rho=20°\ 42'\cdot 8$
4	"	fair	"	"	"	$\rho=20°\ 43'\cdot 5$
12	"	poor	"	"	"	$\rho=20°\ 41'\cdot 5$
37	"	all sorts	"	"	"	$\rho=20°\ 42'\cdot 6$

For p, $(02\bar{2}1)$

3 readings,	very	good signals,	average	value	of	$\rho=37°\ 07'\ \frac{1}{3}$
6	"	good	"	"	"	$\rho=37°\ 03'\ \frac{1}{2}$
6	"	fair	"	"	"	$\rho=37°\ 07'\ \frac{1}{2}$
6	"	poor	"	"	"	$\rho=37°\ 17'\ \frac{1}{3}$
12	"	very poor	"	"	"	$\rho=37°\ 12'\ \frac{1}{3}$
Mean of 24	"	selected	"	"	"	$\rho=37°\ 09'\cdot 0$
Mean of 15	"	best	"	"	"	$\rho=37°\ 05'\cdot 8$

(The word selected as used above means that, using the averages found in the columns above, the whole number of readings whose signals were very good, good and fair was summed with half the number of readings whose signals were poor and very poor, and the general average then taken, weighted in this manner to avoid giving undue influence to the relatively large number of inferior readings.)

Using the formula $pp_0\sqrt{3}=\tan\rho$ and the above values, we obtain,

$$p=1,\quad \rho=20°\ 42'\cdot 6,\quad p_0=0\cdot 21828$$
$$p=2,\quad \rho=37°\ 05'\cdot 8,\quad p_0=0\cdot 21830.$$

Taking the value of $p_0=0\cdot 2183$ we have from the relation

$$c=\tfrac{3}{2}\,p_0,\quad a:c=1:0\cdot 3274.$$

This value of p_0, which is based on a large number of measurements, is probably to be given preference over Miller's value; it is exceedingly near the value of p_0 for beyrichite found by Laspeyres.

Found, millerite	$p_0=0\cdot 2183$
Miller "	$p_0=0\cdot 2197$
Laspeyres, beyrichite	$p_0=0\cdot 2185$

Accordingly a table of angles based on the new value is presented to replace that given in Goldschmidt, Winkeltabellen, p. 242. It contains the new forms, and in a supplement those doubtful ones not yet fully established. This constitutes Table I.

Table I—Millerite.

Hexagonal. **Rhombohedral-hemihedral.**

$c=0{\cdot}32745$ $lgc=9{\cdot}51514$ $lga_0=0{\cdot}72341$ $lgp_0=9{\cdot}33905$ $a_0=5{\cdot}2895$ $p_0=0{\cdot}2183$. (G_2)

Number.	Letter.	Symb. G_2.	Bravais.	ϕ.	ρ.	ξ_0.	η_0.	ξ.	η.	Prisms x / $x:y$.	y.	$d = tg\,\rho$.
1	*c*	0	0001	0° 00′	0° 00′	0° 00′	0° 00′	0° 00′	0° 00′	0	0	0
2	*b*	∞	$10\bar{1}0$	30° 00′	90° 00′	90° 00′	90° 00′	30° 00′	60° 00′	0·5773	∞	∞
3	*a*	∞0	$11\bar{2}0$	0° 00′	90° 00′	0° 00′	90° 00′	0° 00′	90° 00′	0	∞	∞
4	*k*	4∞	$21\bar{3}0$	10° 53′	90° 00′	90° 00′	90° 00′	10° 53′	79° 06′	0·1924	∞	∞
5	*d*	$\frac{11}{5}\infty$	$72\bar{9}0$	17° 47′	90° 00′	90° 00′	90° 00′	17° 47′	72° 13′	0·3207	∞	∞
6	*r*	1	$10\bar{1}1$	30° 00′	20° 42′	10° 42′	18° 08′	10° 11′	17° 50′	0·1890	0·3274	0·3781
7	*v*	$\frac{5}{2}$	$50\bar{5}2$	30° 00′	43° 28′	25° 18′	39° 18′	20° 05′	36° 30′	0·4726	0·8186	0·9452
8	*p*	−2	$02\bar{2}1$	30° 00′	37° 06′	20° 42′	33° 13′	17° 33′	31° 29′	0·3781	0·6544	0·7562
9	*e*	$-\frac{1}{2}$	$01\bar{1}2$	30° 00′	10° 42′	5° 24′	9° 18′	5° 20′	9° 15′	0·0945	0·1634	0·1890
10	*s*	41	$21\bar{3}1$	10° 53′	45° 00′	10° 42′	44° 29′	7° 41′	43° 59′	0·1890	0·9823	1·0003
11	*u*	−21	$\bar{4}\bar{1}53$	19° 06′	38° 00′	10° 42′	28° 37′	9° 25′	28° 12′	0·1890	0·5457	0·5775
?	*i*	2∞	$41\bar{5}0$	19° 06′	90° 00′	90° 00′	90° 00′	19° 06′	70° 53′	0·3464	∞	∞
?	*f*	$\frac{17}{5}\infty$	$9{\cdot}4{\cdot}\bar{1}\bar{3}{\cdot}0$	12° 31′	90° 00′	90° 00′	90° 00′	12° 31′	77° 28′	0·2220	∞	∞
?	*g*	$\frac{19}{6}\infty$	$31{\cdot}18{\cdot}\bar{4}\bar{4}{\cdot}0$	13° 17′	90° 00′	90° 00′	90° 00′	13° 17′	76° 42′	0·2361	∞	∞
?	*h*	3	$30\bar{3}1$	30° 00′	48° 36′	29° 33′	44° 29′	22° 01′	40° 31′	0·5671	0·9823	1·1343
?	*t*	−3	$03\bar{3}1$	30° 00′	48° 36′	29° 33′	44° 29′	22° 01′	40° 31′	0·5671	0·9823	1·1343
?	*x*	4	$40\bar{4}1$	30° 00′	56° 31′	37° 06′	52° 38′	24° 39′	46° 15′	0·7562	1·3098	1·5724
?	*j*	5	$50\bar{5}1$	30° 00′	62° 07′	43° 23′	58° 35′	26° 14′	49° 57′	0·9452	1·6372	1·8905
?	*l*	−9	$09\bar{9}1$	30° 00′	73° 37′	59° 33′	71° 15′	28° 40′	56° 11′	1·7014	2·9470	3·4030
?	*m*	−18·18	$0{\cdot}18{\cdot}\bar{1}\bar{8}{\cdot}1$	30° 00′	81° 38′	73° 37′	80° 22′	29° 41′	59° 02′	3·4030	5·8940	6·8060
?	*n*	$\frac{3}{2}\ \frac{1}{2}$	$5{\cdot}2{\cdot}\bar{7}{\cdot}6$	13° 59′	21° 29′	5° 24′	20° 54′	5° 03′	20° 44′	0·0945	0·3820	0·3935
?	*o*	$\frac{5}{3}\ \frac{1}{3}$	$7{\cdot}4{\cdot}\bar{1}\bar{1}{\cdot}9$	8° 57′	22° 03′	3° 36′	21° 48′	3° 21′	21° 46′	0·0630	0·4002	0·4051
?	*q*	$-\frac{3}{4}\ \frac{5}{4}$	$\bar{6}\bar{1}74$	22° 24′	31° 47′	13° 18′	29° 49′	11° 35′	29° 09′	0·2363	0·5730	0·6198
?	*w*	$\frac{8}{5}\ \frac{3}{5}$	$42\bar{6}5$	10° 53′	21° 48′	4° 19′	21° 27′	4° 01′	21° 23′	0·0756	0·3929	0·4001

Table II shows the character of the combinations observed on the measured crystals, the numbers under each letter indicating the number of faces of that form found on the given crystal.

Table II.

	b	*a*	*k*	*d*	*r*	*p*	*v*	*s*	*u*
A	6	1	.	.	2	.	.	.	.
1	6	.	1	1	1	1	.	.	.
2	6	2	3	2	2	1	.	.	6
3	6	2	1	2	3	3	.	.	.
4	6	2	.	2	3	.	.	.	6
5	3	1	.	.	3	1	.	.	1
6	4	.	.	.	3	3	.	.	.
7	6	6	2	.	3	.	.	.	3
8	6	.	.	.	3	3	.	.	.
9	6	4	.	4	3	3	.	.	1

	b	*a*	*k*	*d*	*r*	*p*	*v*	*s*	*u*
12	6	4	.	1	3	.	.	.	.
13	6	2	.	[illegible]	.	.	.	.	.
14	4	.	.	.	.	3	.	.	1
15	*x*	.	.	.	*x*	*x*	.	.	*x*
16	4	.	.	.	3	3	2	.	.
17	3	.	.	.	3	3	.	.	.
18	3	.	.	.	3	3	1	.	.
19	1	.	.	1	3	1	.	5	1
20	1	.	.	.	3	3	2	.	.
21	1	.	.	.	3	3	2	.	.
22	.	.	.	.	3	.	.	3	.
23	2	.	.	.	1	.	1	.	.
24	6	.	.	.	1	3	.	.	.
25	2	.	.	.	2	1*	.	.	.
26	3	.	.	.	1	.	.	.	2
27	3	.	.	.	1*	.	.	.	4
30	2	.	.	.	3	.	.	.	.
31	.	.	.	.	x*	.	.	.	.

(The star indicates that the crystal was doubly terminated, but the faces on one end only are given.)

The forms may be characterized as follows:

Prisms.

The prisms usually show a triangular cross-section with rounded corners, but sometimes the cross-section is nearly circular. This is due in part to the development of three or four prisms, partly or completely, and in part to the oscillatory combination of these prisms. The prism zone is badly striated in its length from this cause and in measurement yields signals every few degrees.

b, $(10\bar{1}0)$. Twenty-four out of the twenty-eight crystals which were measured systematically showed faces of the first order prisms, and eleven of these showed all its faces. It is easily the dominant form on the mineral, and it is the least striated of any prism. In most cases it was developed trigonally.

a, $(11\bar{2}0)$. The second order prism was also undoubtedly present on nine crystals, although but one had every face. Its faces when large were considerably striated.

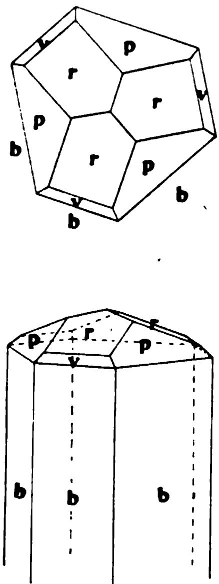
k, $(21\bar{3}0)$. This known prism was found developed incompletely, but none the less surely on four crystals. Its faces were narrow and poorly characterized.

d, $(72\bar{9}0)$. This new prism was found developed incompletely on seven crystals, and the data establishing it are given in full in the following table:

Crystal.	Signal.	Reading. ϕ	
1	very poor	16° 48′	
2	very poor	17° 30′	
2	very poor	17° 33′	
3	poor	17° 58′	
3	poor	17° 59′	
4	good	17° 47′	
4	very good	17° 51′	
9	fair	17° 11′	
9	good	17° 42′	
9	poor	18° 25′	
9	fair	18° 26′	
12	very poor	17° 45′	
19	fair	16° 48′	
Average	fair to poor	17° 47′	average.
Calculated		17° 47′	

The calculated value of ϕ for this form is curiously in exact agreement with the mean of the measurements. So, although

3



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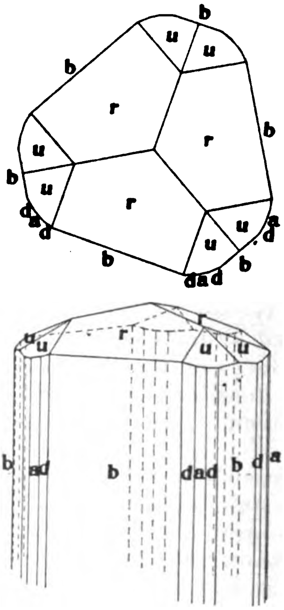

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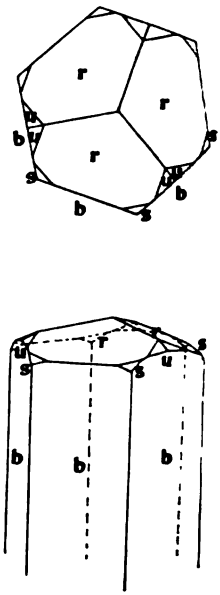


this precise agreement is of course mere chance, it is near enough to establish the form and there are faces enough, well distributed among the crystals, to confirm it. Its faces are narrow and quite indistinguishable from the oscillation planes with which it is associated.

Rhombohedrons.

These are the chief terminating faces whether they occur as cleavage or as crystal planes. The faces, when crystal planes, are not very bright, although the markings and roughnesses which make them dull are never well characterized.

r, $(10\bar{1}1)$. The unit rhombohedron was found on all but two of the measured crystals. In a very few instances it was certainly cleavage; and in a few cases it was impossible to say whether cleavage or natural growth had produced the facet. It was developed in relatively large and perfect facets, constituting the dominant terminating form. While not always of good reflecting quality, the faces were usually definite and exhibited no definite markings.

p, $(02\bar{2}1)$. Next to *r* the new rhombohedron *p* is best developed as a termination. It is not found as cleavage. It occurs in rather large faces of dull reflecting power for the most part. It is missing from nine crystals only out of the twenty-eight measured, occurring, therefore, with less frequency than *r*. No definite markings were seen on its faces. The observations on which it is based are stated in summary form on p. 349.

v, $(50\bar{5}2)$. This rhombohedron, noted by Miller in his first paper, but omitted from his Mineralogy, occurs on five of the crystals, three of them, singly terminated, showing two faces each. The measurements on which the form is based follow.

Crystal.	Signal.	Readings.		
		ϕ	ϕ_1*	ρ
16	good	$\bar{2}9°\ 39'$	$29°\ 39'$	$44°\ 03'$
16	good	$\bar{1}49°\ 41'$	$29°\ 41'$	$43°\ 57'$
18	very good	$\bar{1}49°\ 19'$	$29°\ 19'$	$43°\ 23'$
20	poor	$\bar{3}0°\ 42'$	$30°\ 42'$	$43°\ 33'$
20	good	$\bar{1}50°\ 07'$	$30°\ 07'$	$43°\ 25'$
21	fair	$\bar{2}9°\ 52'$	$29°\ 52'$	$43°\ 24'$
21	good	$\bar{1}50°\ 10'$	$30°\ 10'$	$43°\ 25'$
24	fair	$89°\ 31'$	$29°\ 31'$	$43°\ 51'$
Average	very good to fair		$29°\ 53'$	$43°\ 39'$
Calculated			$30°\ 00'$	$43°\ 23'$

Scalenohedrons.

These forms are entirely new to millerite. They are present on the Orford mineral as small but distinct facets on over half the crystals measured. The faces are fairly bright, yielding good images, and for the most part they are not pitted or striated.

s, $(21\bar{3}1)$. This scalenohedron occurs on two singly terminated crystals, in one case five of its faces being present. The measurements which establish it are given below.

* ϕ_1 is the value of ϕ referred to the first sextant on the right, that is, the difference between ϕ and the nearest multiple of 60°.

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
19	fair	$\bar{1}$1° 13′	11° 13′	44° 59′
19	very poor	$\bar{4}$9° 03′	10° 57′	44° 59′
19	good	$\bar{1}$30° 55′	10° 55′	45° 01′
19	good	$\bar{1}$69° 06′	10° 54′	45° 01′
19	very poor	109° 10′	10° 50′	45° 01′
22	fair	$\bar{4}$9° 24′	10° 36′	44° 55′
22	fair	$\bar{1}$31° 16′	11° 16′	45° 00′
22	poor	$\bar{1}$69° 29′	10° 31′	45° 00′
	Mean of 8		10° 54′	44° 59′·5
	Calculated		10° 53′·	45° 00′·

The form is seen to be well established by these results.

u, (4$\bar{1}$53). This scalenohedron occurs on ten crystals, in two cases all its faces being present. The faces, however, are not very bright. They are rough and pitted for the most part and the images are only fair. The data follow.

This scalenohedron and the uncertain ones, *n*, *o*, *q* and *w*, lie in the zone with the rhombohedrons *r* and *p*, and their faces generally appear as striations or roundings of the edges between *r* and *p*, or as shown in figure 4, without *p*.

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
2	extremely poor	20° 02′	20° 02′	30° 07′
2	fair	40° 23′	19° 37′	30° 33′
2	good	139° 21′	19° 21′	30° 03′
2	good	160° 57′	19° 03′	30° 01′
2	extremely poor	$\bar{1}$01° 08′	18° 52′	30° 01′
2	very poor	$\bar{7}$8° 14′	18° 14′	30° 01′
4	very poor	40° 33′	19° 27′	30° 11′
4	extremely poor	139° 42′	19° 42′	30° 11′
4	extremely poor	160° 26′	19° 34′	30° 11′
4	extremely poor	$\bar{1}$00° 00′	20° 00′	30° 11′
4	extremely poor	$\bar{8}$0° 05′	20° 05′	30° 11′
4	extremely poor	20° 37′	20° 37′	30° 11′
5	very poor	141° 36′	21° 36′	30° 40′
7	extremely poor	138° 41′	18° 41′	30° 40′
7	extremely poor	161° 25′	18° 35′	30° 40′
7	extremely poor	$\bar{7}$9° 32′	19° 32′	30° 40′
9	poor	$\bar{9}$9° 52′	20° 08′	30° 42′
19	very poor	159° 51′	20° 09′	30° 45′
26	poor	41° 20′	18° 40′	30° 00′
26	very poor	18° 51′	18° 51′	29° 49′
27	poor	41° 07′	18° 53′	29° 42′
27	poor	100° 12′	19° 48′	29° 42′
27	very poor	161° 48′	18° 12′	29° 42′
27	very poor	138° 38′	18° 38′	29° 42′
	Mean of all (24)		19° 24′·	30° 04′
	Mean of best		19° 05′	30° 07′
	Calculated		19° 06′	30° 00′·

Doubtful Forms.

The following forms, for one reason or another, given in detail under each form, are presented as possibly present on the species, but not as established beyond cavil.

i, (41$\bar{5}$0). This form was reported by Laspeyres, but not very well established by his measurements. We obtained poor measurements partly confirming it, but the form is still in doubt, neither his measurements nor ours being good enough to certify it. Our measurements follow.

Crystal.	Signal.	Reading. ϕ
2	extremely poor	18° 52′
2	extremely poor	18° 58′
2	poor	19° 01′
Average	very poor	18° 57′
Calculated		19° 06′·4

The agreement of our measurements with the calculations is better than that of Laspeyres's measurements, but the faces noted were all on one crystal, and two of them were very doubtful.

f, (9·4·$\bar{13}$·0). This prism is new and the measurements on which it is based follow.

Crystal.	Signal.	Reading. ϕ
7	fair	12° 26′
12	poor	12° 29′
14	very good	12° 29′
Average	fair to good	12° 28′
Calculated		12° 31′·2.

The agreement is close enough to establish the form, but the faces are few in number, though well distributed. The signals, however, are good, and in the case of crystal 14, at least, the reading corresponds to a definite face of good quality which can be seen in the goniometer. In this respect the face differs from most of the oscillation planes and, moreover, it is placed very close to its computed position. Therefore the form is regarded as probable, but confirmation is necessary.

g, (31·13·$\bar{44}$·0). This prism, so far as our measurements go, is better established than the form *i*, and so is given, but it has complex indices and altogether is a doubtful form.

Crystal.	Signal.	Readings. ϕ
2	extremely poor	13° 11′
8	extremely poor	13° 22′
14	good	13° 19′
Average	poor	13° 17′·3.
Calculated		13° 17′

Besides the signals reflected from faces of these forms which are more or less well established, there were read, in the prism zone, signals reflected from faces in thirty-two positions (reduced to the positive sextant) which corresponded more or less well to prisms of complex indices. For the most part only one face of each of these forms was seen, and the signals were generally of very poor quality. These facts together with the complexity of the indices deduced, and the certainty of the occurrence of oscillation-vicinals whose signals correspond to no prism however complex, render the establishment of any of them very doubtful. Therefore all are rejected and none of the data is published.

Doubtful Rhombohedrons.

t, (03$\bar{3}$1). This rhombohedron was reported by Miller on the strength of a contact measurement on a rough terminated crystal. We can not confirm the form, but one face on one crystal was found approximating to its position.

Crystal.	Signal.	Readings. ϕ	ρ
24	very poor	30° 00′	48° 56′
Calculated		30° 00′	48° 36′

h, (30$\bar{3}$1). This rhombohedron is new and very doubtful, relying for its establishment on two measurements on two different crystals.

Crystal.	Signal.	Readings. ϕ	ρ
23	very poor	30° 00′	48° 42′
24	fair	150° 00′	48° 10′
Mean	poor	30° 00′	48° 26′
Calculated		30°	48° 36′

The form is therefore certainly indicated, but by no means established.

x, (40$\bar{4}$1). This form also is new and rests on a single measurement whose signal was of fair quality. The measured value for ρ was 56° 34′; the calculated value of ρ is = 56° 31′49″; apparently the form only lacks the finding of more faces to establish it.

j, (50$\bar{5}$1). One face only supports this form.

Crystal.	Signal.	Readings. ϕ	ρ
23	poor	29° 46′	62° 26′
Calculated		30° 00′	62° 07′

l, (09$\bar{9}$1). Only one face of this form was found. This gave a fair signal showing a definite face.

Crystal.	Signal.	Readings. ϕ	ρ
25	fair	29° 25′	73° 05′
Calculated		30° 00′	73° 37′

m, $(0\cdot18\cdot\bar{18}\cdot1)$. Only one face of this form was found which yielded two signals of fair quality.

Crystal.	Signal.	Readings. ϕ	ρ
24	fair	30° 00′	82° 32′
24		30° 00′	80° 20′
Calculated		30° 00′	81° 38′

No stress is laid on the probability of the occurrence of *l* and *m*. The faces were plainly visible in both cases.

Doubtful Scalenohedrons.

n, $(52\bar{7}6)$. This form was found on three crystals, in one case four of its faces being present. The data follow:

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
5	good	104° 52′	15° 08′	21° 18′
5	poor	133° 21′	13° 21′	21° 18′
8	poor	$\bar{1}33$° 14′	13° 14′	21° 22′
8		$\bar{4}6$° 39′	13° 21′	21° 22′
8		73° 01′	13° 01′	21° 22′
8	very poor	$\bar{1}66$° 45′	13° 15′	21° 22′
14	poor	$\bar{1}67$° 14′	12° 46′	21° 26′
Mean	poor	....	13° 26′·5	21° 21′
Calculated		....	13° 54′	21° 29′

Although we have left the form in doubt it is clear that it is more than indicated. The agreement of measurements with calculations is only fair, but there are many faces well distributed.

o, $(7\cdot4\cdot\bar{11}\cdot9)$. This form was found on three crystals, in one case four faces being present. The data are given in full:

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
5	poor	$\bar{8}$° 52′	8° 52′	22° 03′
5	very poor	$\bar{5}0$° 58′	9° 02′	22° 00′
8	extremely poor	$\bar{7}$° 30′	7° 30′	21° 22′
18	poor	$\bar{9}$° 51′	9° 51′	21° 19′
18	extremely poor	$\bar{1}71$° 40′	8° 20′	21° 51′
18		$\bar{1}28$° 24′	8° 24′	21° 36′
18	poor	$\bar{4}9$° 46′	10° 14′	21° 09′
Mean	very poor	....	8° 53′	21° 37′
Calculated		....	8° 57′	22° 03′

This form, therefore, is not to be rejected without consideration although the data cannot be said to establish it.

q, $(\bar{6}\bar{1}74)$. This form rests on two readings made on a single crystal. This crystal was the richest in forms of any measured. The agreement is not very bad. The form is at least indicated.

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
2	poor	$\bar{8}3°$ 05′	23° 05′	32° 00′
2	very poor	$\bar{9}7°$ 33′	22° 27′	32° 00′
Mean	poor	....	22° 46′	32° 00′
Calculated		....	22° 24′	31° 47′

w, $(42\bar{6}5)$. Only one reading supports this form. It in consequence is very doubtful.

Crystal.	Signal.	Readings. ϕ	ϕ_1	ρ
5	fair	70° 26′	10° 26′	21° 47′
Calculated		....	10° 53′	21° 48′

Résume.

The Orford millerite has yielded a number of terminated, measureable crystals from which the new axial ratio $a:c=1:0·2183$ is calculated. In addition to the forms previously known, one new prism, two rhombohedrons and two scalenohedrons are definitely established and a number of uncertain forms observed but not established.

The presence of a gliding plane parallel to the negative rhombohedron, along which pressure twins of great perfection can be easily obtained, is also determined.

Millerite has been thought to be hemimorphic like the nearly related cadmium sulphide, greenockite, and has been so classified by Groth. The sharply defined trigonal character of many of the prisms of Orford millerite seem to give some basis for this assumption; and doubly terminated crystals were therefore eagerly sought for in the hope that the question might be settled by definite observations. A few crystals doubly terminated were found but they were poor crystals and so far as measurements could be made upon them showed no unlikeness between the two ends. Our evidence on this matter is therefore not conclusive.

On the surface of a single hand specimen of very rich green chrome garnet which was originally covered with a thin layer of calcite, there appeared on the removal of the latter with acid a number of tiny clusters of crystals of a gray to white metallic mineral which seem to be rammelsbergite, an arsenide of nickel. The crystals are minute and invariably so deeply striated that no satisfactory measurements could be obtained. Still inasmuch as this mineral has never been found before in crystals that permitted of measurement except in one zone, a number of the crystals were studied carefully and a provisional axial ratio was calculated for the species. It was found to be like the other

members of the marcasite group in habit and the flat dome which was found on all measured crystals was taken by analogy with arsenopyrite as the brachydome (014). The prism zone was so deeply striated that no reliance could be placed on the readings made from it; but an orthodome was found on nearly all the crystals very faintly developed but which gave fairly uniform readings for ρ. This was taken as (102), a choice that gave the simplest indices for the prism forms and a ratio most nearly like that of the other members of the group, although differing widely from any of them. The observations follow:

Rammelsbergite ?.

$$\left.\begin{array}{llll} 0\tfrac{1}{4} \text{ av. of } 7, & \phi = 0^\circ\ 00', & \rho = 16^\circ\ 06' \\ \tfrac{1}{2}0 \text{ av. of } 4, & \phi = 90^\circ\ 00', & \rho = 45^\circ\ 15' \end{array}\right\} \begin{array}{l} p_o = 2{\cdot}0176 \\ q_o = 1{\cdot}1545 \end{array}$$

$$a : b : c = 0{\cdot}57222 : 1 : 1{\cdot}1545$$

Form.		Calculated.		Measured.		No. of
G.	Miller	ϕ	ρ	ϕ	ρ	observations.
0∞	010	00° 00′	90° 00′	00° 00′	90° 00′	6
∞	110	60° 13′	90° 00′	60° 44′	90° 00′	3
$\infty 2$	120	74° 02′	90° 00′	74° 26′	90° 00′	4
2∞	210	41° 09′	90° 00′	42° 30′	90° 00′	2
$0\frac{1}{4}$	014	00° 00′	16° 06′	00° 00′	16° 06′	7
$0\frac{1}{3}$	013	00° 00′	21° 03′	00° 00′	20° 30′	2
$0\frac{1}{2}$	012	00° 00′	29° 59′	00° 00′	29° 45′	1
02	021	00° 00′	66° 35′	00° 00′	66° 50′	1
$\frac{1}{2}0$	102	90° 00′	45° 15′	90° 00′	45° 15′	4

The amount of the mineral present on our specimens was so small that sufficient for analysis could not be secured. Its doubtful determination as rammelsbergite is based on blowpipe reactions for arsenic and nickel obtained on minute crystals. No test for sulphur could be obtained. It is hoped that more and better material may ultimately be obtained which will enable the character of this mineral to be definitely established.

EXPLANATION OF THE FIGURES.

Fig. 1 shows a photograph of a specimen from which calcite has been partly removed by solution in hydrochloric acid. Several large straight prisms of the millerite may be seen still partly embedded in the calcite. On the surface of the pyroxene matrix may be seen several smaller broken and twisted millerite crystals.

Fig. 2 shows a twin crystal produced by pressure, twinned parallel to the rhombohedron *e*, $(01\bar{1}2)$. The upper termination is formed by single planes of the two cleavages, parallel to *r* and *e*; the lower termination is by a single plane of the *r* cleavage.

Fig. 3 shows in plan and perspective the commonest type of crystal found. The proportions of the rhombohedrons may vary but some or all of the faces of the three are generally found.

Fig. 4 and Fig. 5 show the mode in which the scalenohedrons occur in combination. Of these forms *u* is much the more frequent, *s* having been observed on but two crystals.

Harvard Mineralogical Laboratory,
June 1904.

ART. XXXVIII.—*Unconformity of the Cretaceous on Older Rocks in Central New Mexico;* by CHARLES R. KEYES.

IN New Mexico Cretaceous sedimentation is enormously developed. The total thickness of the strata referable to this age cannot be less than 7000 feet.

In eastern New Mexico and Texas the sequence of the Cretaceous formations is quite complete. Both the Lower Cretaceous and the Upper Cretaceous are well represented. Below are the "Red Beds," probably composed partly of Triassic sandstones and shales and partly of Carboniferous layers of similar lithologic characters. These attain a thickness of 2000 feet and upwards. Then below all these are the great Carboniferous limestones, which are about 2000 feet thick and which form the backslopes of most of the block mountains of the Basin region. The generalized geological section for New Mexico may be tabulated as follows:

Ages.	Systems.	Thickness.	Formations.	Rocks.
Cenozoic	Quaternary	200		Gravels
	Tertiary	200	Galisteo	Sandstones
		800	Puerco	Clays
Mesozoic	Cretaceous	2000	Laramie	Sandstones
		1500	Montana	Shales
		800	Colorado	Shales
		400	Dakota	Sandstones
		800	Comanche	Sandstones
	Triassic	1000	Cimarron	Shales
Paleozoic	Carboniferous	1000	Bernalillo	Shales
		300	Madera	Limestones
		300	Sandia	Limestones
		200	Lake Valley	Limestones
	Devonian	200	Chloride	Limestones
	Ordovician	400	Pinos Altos	Limestones
	Cambrian	300	Tonto	Sandstones
Azoic	Algonkian	300	Chuar	Shales
		1000	Grand Canyon	Sandstones
		500	Vishnu	Quartzites
	Archean	2000		Schists

The relationships of the Cretaceous system to the other formations, as displayed in central New Mexico, have long been a puzzle. Throughout the region the Red Beds constitute a conspicuous and important formation. Owing, how-

ever, to the peculiar position they occupy when well exposed on the lower backslopes of the block mountains, with the Cretaceous coming in immediately, the exact disposition of the two great formations is seldom clearly discernible. Then, too, at the bases of mountains vast plains stretch away, which are deeply covered by gravels, sands and clays washed down from the higher elevations, and which cover effectually all traces of the indurated rocks beneath. While these underlying rocks usually are more or less highly inclined, they have been completely bevelled off to a surface that is as even and level as the plains themselves.

That the Cretaceous rocks in central New Mexico rest unconformably on the older formations has been for some time surmised. The difficulty has been to obtain indisputable evidence in support of this hypothesis. This proof has lately been secured; and the facts are of exceptional interest.

1

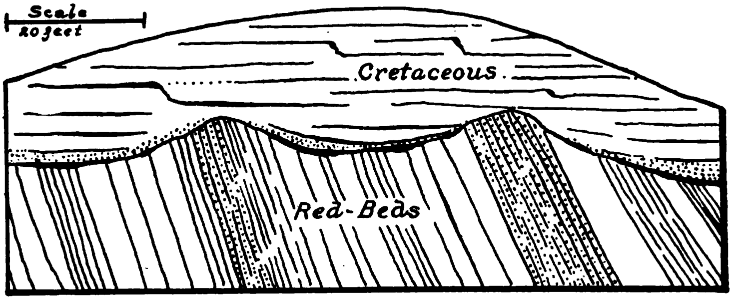


Fig. 1. Cretaceous and Red Beds at Tejon, New Mexico.

In a number of instances the Cretaceous sandstones have been found to repose apparently in perfect conformity upon the Carboniferous limestones. There is no evidence whatever of the existence of the great thickness of Red Beds between sandstone and limestone. If the Red Beds ever existed there they were swept cleanly away from the surface of the limerock. But the bedding planes of the Carboniferous and Cretaceous formations were to all appearances parallel.

East of the Sandia Mountains the Cretaceous deposits extend almost uninterruptedly to the Texas line. At the north end of the range where the backslope of Carboniferous limestone begins to sink under the plains, a small stream has cut deeply through the Cretaceous sandstones into the Red Beds beneath. At this place the Red Beds are standing on end, while the yellow Cretaceous beds are lying very nearly horizontally. The relationships are best indicated by diagram (figure 1).

A still more instructive section is displayed in the canyons cutting the Chupadera Mesa, 50 miles east of Socorro. The surface rock of the great mesa is horizontally disposed Cretaceous sandstone, rather massively bedded and yellowish in color. The dissecting canyons are 300 to 400 feet deep. They disclose the blue Carboniferous limestones in many places. A number of enormous dikes of gray trachyte traverse the district where the limestones are displayed. Along these dikes are large deposits of iron ore. On either side of the dike the limestone is abruptly upturned, often nearly to a vertical attitude. The cross-section is shown in the subjoined cut (figure 2).

2

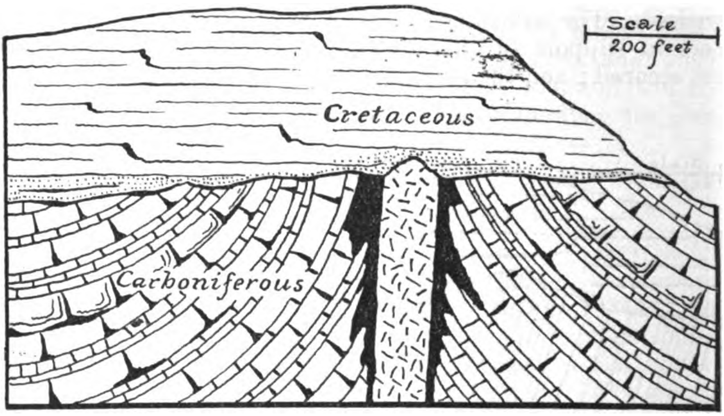


FIG. 2. Unconformity of Cretaceous on Carboniferous.

At this particular point the Cretaceous beds repose horizontally, while in a distance of a thousand feet the Carboniferous limestones change in dip from horizontal to vertical. The dike is 200 feet thick. The iron ore on either side is of varying thickness, and fills the jagged edges of the broken limestone.

With the recognition of an enormous erosion interval in central New Mexico prior to the deposition of the Cretaceous sandstones, the working out of the geology of the region is greatly simplified. Many hitherto inexplicable phenomena now find easy solution. The Cretaceous of the region is all Upper Cretaceous. Nowhere have the Lower Cretaceous beds been found.

The duration of the erosion interval was thus probably equivalent to the sedimentation period of the entire Lower Cretaceous of the Texas area.

New Mexico School of Mines, Socorro, August 30, 1904.

ART. XXXIX.—*A Peculiar Occurrence of Bitumen and Evidence as to its Origin;* by WM. CONGER MORGAN and MARION CLOVER TALLMON. (With Plates XVIII and XIX.)

Summary.

THE following is a description and an account of the examination of a fossil egg from Arizona. When discovered it was enclosed in a limestone matrix which has kept the specimen in a very fine state of preservation. Crystallized colemanite and a tarry material resembling natural asphalts are found within the eggshell. All the evidence which can be collected from the specimen indicates that the asphalt-like substance is part of the original contents of the egg which has become bitumized.

Introduction.

Very few instances of the occurrence of eggs in the fossil state have been recorded. The fossil eggs of New Zealand birds are only shells which have been preserved by reason of their thickness and strength. The Chelonian eggs of Tertiary age from Auvergne, France, are simply shells filled with hardened mud. An interesting fossil egg from the American Miocene has been described by Mr. Oliver C. Farrington,* and has been considered the egg of a duck.

The specimen described in this paper was brought to the attention of Professor John C. Merriam some months ago by Mr. G. A. Helmore of San Francisco. It had been in Mr. Helmore's possession for some years, and was obtained by him from a prospector who found it in a large pebble embedded in placer gravels on the Gila River in Arizona. Mr. Helmore, being unwilling to part with the specimen, has kindly loaned it to the University of California for study and description. To Professor Merriam the authors wish to acknowledge their indebtedness for valuable suggestions during the course of the work.

Occurrence.

Unfortunately, the information which we have concerning the occurrence of this specimen does not give us very definite evidence concerning its age. The encapsuled egg is said to have been a pebble in gravels some distance above the present level of the river. If, as has been supposed, the gravels are bench deposits, the egg is at least as old as the Quaternary. If they are of recent origin, we can still hardly suppose it younger than Quaternary, as it is only under the most extraordinary circumstance that deposits of recent origin can occur as hard pebbles in recent conglomerates.

* Field Columbian Museum, Pub. 35, vol. i, No. 5, Geological Series. A Fossil Egg from South Dakota.

Description.

The egg as found forms the center of a rounded mass of hard calcareous rock, which may be called the capsule or matrix. Its appearance is that of an ordinary irregularly-shaped river pebble, about $3\frac{1}{2} \times 4 \times 5$ inches in dimensions. It is well worn by the action of water, and shows striations in a plane parallel with the longer diameters, apparently due to differential weathering of the thin layers of the matrix. By a blow of a pick a piece was broken out of one side of the pebble, revealing a smooth inner core, from the appearance of which the finder had no hesitation in pronouncing it a fossil egg embedded in rock. When the specimen came into our possession, part of the surrounding matrix had been removed and the egg broken open. (Pl. XVIII, figs. 2 and 4.)

In order to expose fresh surfaces for observation the matrix was completely removed. It separated readily and exposed what appears externally to be a typical egg in all respects. (Pl. XVIII, fig. 1.) It is oval in shape, but little removed from an ellipsoid, however, and measures 62×40^{mm} ($2{\cdot}44 \times 1{\cdot}57$ inches). Its shape indicates very clearly that it belongs to the class of water-birds, and by comparison with the eggs of birds of the present time, it is found to correspond closely with the type of egg laid by the cormorant. The character of the shell is entirely unlike these rough chalk-coated eggs, however, but shows a finely pitted surface with some degree of polish such as is found in eggs of the duck family. The minutest markings of the shell are preserved in the matrix, moreover, and in this there is no evidence of any scratches such as usually occur in the chalky layer of cormorant's eggs. It is true that the shell proper lying underneath the outer chalky layer of a cormorant's egg shows a pitted surface much like that of the present fossil specimen. It seems improbable, however, that the chalky layer could have been washed off without injury being done to the egg, neither is it probable that it was firmly united with the matrix and pulled away in separating the egg-shell from the rock.

While the specimen most resembles in shape the type egg of the cormorant, it is also much like the egg of the larger grebes or herons, the American bittern or limpkin. Again, while the ratio of the short to the long diameter is somewhat less than that of the typical egg of the duck, its dimensions correspond almost exactly with measured eggs of many of the larger species of this family, thus showing that its divergence from the type is not greater than could be accounted for by individual variation.

In microscopic structure the same similarity is apparent. Under the lens the shell of a wild goose or of a duck's egg is

practically indistinguishable from the fossil shell, which shows distinctly the two characteristic layers, the outer one veined, the inner one prismatic. (Pl. XIX, figs. 2*a* and 2*b*.) The shell is light buff in tint, but any inference from its present to its original color would hardly be significant. It is probable that when this egg was deposited the region was not near to the sea. Under geographic conditions similar to those now obtaining, ducks would be more numerous than any of the other possible forms, and the probabilities, therefore, favor anatine origin of the egg.

Since it was not desirable to mutilate the specimen unnecessarily a quantitative analysis of the shell was not possible. Qualitative analyses of the shell of the fossil egg and the shell of a wild-goose's egg were made in parallel, on approximately equal amounts of material in equal volumes of solution with the same number of drops of the different reagents. With the exception of organic matter the fossil gave tests for every element found in the egg of the goose apparently to the same degree, the only difference noticeable being that the fossil contained a trifle more iron.

Taking into consideration the facts that the fossil eggshell is in chemical composition similar to, and in physical structure practically indistinguishable from, the shells of birds' eggs of the present time, the hypothesis that the material of the fossil eggshell as it exists to-day is the same as was present originally seems unquestionable. Moreover, the minute tracings of the shell are reproduced on the inner surface of the surrounding capsule. This fact makes it necessary to assume that the egg was encased very soon after it was deposited in the nest, and that subsequently it has been subjected to no conditions likely to modify its microscopic structure.

Contents.

By far the larger portion of the contents of the egg consists of beautifully crystalline colorless colemanite, showing the characteristic plates, striations, cleavage, hardness, extinctions and other physical properties. (Pl. XIX, fig. 1.) An analysis gives the following composition:

	Calculated.	Found.
CaO	27·21 per cent	27·07 per cent
B_2O_3	50·93 "	51·00 "
H_2O	21·85 "	22·01 "

While the colemanite in many places comes in direct contact with the shell of the egg, in other places it is separated from

it by a tarry material which, wherever it occurs, is invariably in contact with the shell. The main deposit of this tar is assumed to be on the lower side of the egg as it lay buried. (Pl. XIX, fig. 1, *t*.) The contacts between this deposit and the colemanite above it are smooth, gently rounding surfaces, without inclusions of either substance in the other. The second largest deposit of tar is almost diametrically opposite the one just mentioned, on what seems to have been the upper side of the eggshell. While the character of the tar is identical, the nature of the contact is entirely different. A little mass of tar of irregular shape is almost completely surrounded by the colemanite and hangs down from above like a pendant. (Pl. XIX, fig. 1, *t'*.) Other slight deposits of tar in various parts of the egg present only similar phenomena. No inclusions of the colemanite in the tar could be anywhere detected.

The surfaces bounding the cavity in the colemanite in which the tar is included are smooth and roughly spherical. Had the colemanite crystallized freely, we should expect the bounding surfaces to be right-lined and planar, conforming to the faces of the crystals, and not spherical as in the present instance. The shape of any deposit of material subsequently laid down must of necessity correspond to those surfaces on which it is deposited. Considering the inclusion of the tar in the mineral, the shape of the included mass and the nature of the contacts, there seems to be no doubt that the entrance of the colemanite took place after the tar had already accumulated inside the shell. Hence it was that the colemanite crystallized about the tar, the nature of the surfaces of contacts being determined by the tar and not by the crystallizing mineral.

Besides the deposits of tar inside the shell, there is a thin film of the same material between the shell and the matrix, adhering to both. On the inner surface of the matrix, a number of small black prominences are plainly in evidence (Pl. XIX, fig. 3), which, under the lens, seem to be minute deposits of the same tarry material. They readily disappear when the rock is washed off with chloroform, and, after thorough extraction, in place of the prominences little globular cavities or sacks are found. (Pl. XIX, figs. 3 and 4.) The diameters of these openings increase after penetrating beneath the surface of the matrix. Microscopically examined, the limestone about these cavities appears identical in character with that removed from their vicinity. The cavities are found to correspond with visible canals in the eggshell. The number of pits in a given piece of matrix corresponds with the number of visible passages in that part of the shell from which the matrix was removed, the relative distribution of each being about the same. A minute crack in the shell is also filled with tar and

a corresponding tarry ridge is noticeable in the matrix. Since the homogeneity of the matrix offers no evidence to indicate that the little cavities are the remains of passages to the exterior, subsequently filled with more recently deposited material, and since the juxtaposition of cavity in the matrix and canal in the eggshell offers evidence that the cavities were formed from within, there seems to be no reasonable hypothesis other than that the tar at present outside the shell and in the immediate layers of the matrix came from within and was forced outward from the center.

To offer a reasonable explanation of the formation of these pits is not an easy matter. Since they are intimately connected with the canals through the eggshell, and these canals as well as the pits are filled full with tar, it would seem as though some corroding action of the tar might be connected with their formation. Not the slightest acid reaction can be obtained from the tar in any way with litmus or phenolphthalein, however; hence the solution of the limestone would hardly seem to be due directly to the tar.

The ready solubility of calcium carbonate in water containing carbon dioxide naturally suggests itself. However, the formation of carbon dioxide or of organic acids from the original decomposition of the egg can hardly be supposed to have caused the action. It is questionable whether a limestone matrix could form about an egg before its contents had broken down to relatively very stable decomposition products. Moreover, if these pits had been present in the matrix when the colemanite came in, they would in all probability have been filled with this mineral. It is necessary to assume either that these pits did not exist when the colemanite came in, or that they were already filled with tar which prevented the mineral from filling them. Since the tar that fills them unquestionably came from inside the shell, the only force considered sufficient to make a viscous tar leave a large cavity to fill a small pit would be due to the crystallizing colemanite. As the crystals formed, the resulting pressure forced the tar through the larger canals in the eggshell. Through the fine-grained matrix it could not go because of its viscosity.

The fact that the tar filling these pits has an earthy appearance, like that produced in the "weathering" of asphalts, may offer a clue as to the formation of the pits. Oxygen dissolved in the waters percolating through the strata in which this specimen was embedded, might account for a local oxidation of the tar as it emerged from the pores of the eggshell, the carbon dioxide formed producing an initial solution of the material of the capsule. As soon as the matrix was appreciably dissolved, the tar was forced into the new-formed

cavity and the action began again. Since the oxidation would take place over the whole surface of the minute drop exuding from the pore in the shell, the cavity formed would naturally assume the spherical shape which these pits possess.

The Bituminous Material.

The tar is a semifluid substance of very dark brown color, resembling natural asphalts in appearance and physical properties. At 10° C. it is brittle, showing a conchoidal fracture with brilliant surfaces, the edges of the fracture becoming rounded on standing. As the temperature rises it grows softer, until at 100° C. it becomes a fluid with considerable viscosity. Its specific gravity is a trifle less than that of boiling water. It is readily and completely soluble in petroleum ether, turpentine, carbon disulphide and chloroform; much less in acetone and ether, and only very slightly soluble in alcohol even when boiling. No residue of an organic or inorganic nature is left by any of these solvents. In all of these points it resembles the "petroleum-ether-soluble" fraction of all natural asphalts, long known as "petrolene."

In cold fuming nitric acid it is soluble, separating partially a jelly-like mass which resembles silicic acid. If the solution be now poured into water a flocculent precipitate separates, resembling aluminum hydroxide colored slightly with ferric hydroxide. This precipitate is soluble in fuming nitric acid.

If the solution of tar in nitric acid be heated, the jelly-like substance dissolves, and is not completely oxidized by evaporating to dryness. On boiling the residue with dilute nitric acid everything dissolves as the acid concentrates, and when poured into water now gives a flocculent red precipitate like ferric hydroxide, to which reference is made by Day,* in his investigation of gilsonite. This ferric-hydrate-like precipitate, on being heated with water, collects as a thick reddish oil, very slightly soluble in petroleum ether, but readily soluble in alcohol, especially when warmed, thus showing it to be a different body from the original tar.

Concentrated sulphuric acid dissolves the tarry material also, giving a dark red-brown solution which, on treatment with water, gives a precipitate similar to that from fuming nitric acid just described.

By the sodium nitroprusside reaction the tar gives qualitative tests for the presence of sulphur. A comparison of the intensity of color given by tests made on the tar with similar solutions containing known amounts of sodium sulphide would indicate about 0·2 per cent of sulphur in the tar. How much of the total amount present in the tar would escape conversion into

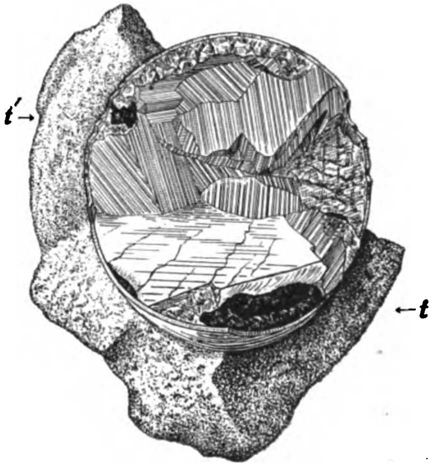
* Jour. Franklin Institute, cxl, p. 239 (1895).

1

2

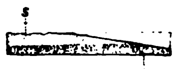
3

4



1

2a



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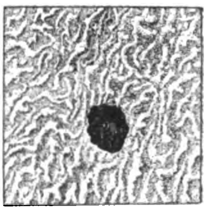

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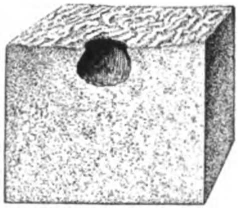

4

alkaline sulphide by heating with metallic sodium is a matter of conjecture only, but it is probable that less than 1 per cent of the tar is sulphur.

Tests for nitrogen, by heating with sodium and precipitating the cyanide as Prussian blue, failed to indicate the presence of this element even when 0·3 gram of tar was treated. Under these circumstances the resulting solutions gave very strong tests for sulphur but not a particle of the blue precipitate could be obtained even on long standing.

In order to ascertain the delicacy of this method of detecting nitrogen in substances of a nature similar to those which might be expected to be present in the tar, qualitative experiments were made with known amounts of pyridine and quinoline. It was found that 0·01 gram of either substance would give a precipitate in such quantity that when diluted to 100^{ccm} and thoroughly mixed, 1^{ccm} would on settling give a distinct indication. Similar results were obtained by mixing the same amounts of pyridine with the tar and then heating with sodium. Certain natural asphalts known to contain nitrogen were tested by this method and gave positive results. Hence it is concluded that the failure to obtain evidence of nitrogen in the present instance was not due to the method. While heating the pyridine with sodium its odor was very apparent in the room, and since it is the most volatile member of this series of compounds it seems highly probable that if nitrogen were present in the tar to the extent of 0·05 per cent it would have been detected.

No evidence of phosphorus could be found, after oxidizing with fuming nitric acid and testing with molybdate solution.

None of the properties, either physical or chemical, which have thus far been set forth, indicate any difference between this tar and some pure natural asphalts.

A combustion of 0·1107 gram of the tar for carbon and hydrogen gave 0·2582 gram carbon dioxide and 0·1058 gram water, indicating 63·6 per cent carbon and 10·6 per cent water. These figures give 25·8 per cent oxygen and other elements, determined by difference. Since nitrogen is absent and sulphur present only in small amounts, oxygen seems to form about one-quarter of the entire substance.

These percentages do not agree even remotely with the figures given by asphalts, which show generally less than 5 per cent of oxygen. Incomplete combustion may possibly explain this discrepancy but there was no evidence of this during the progress of the combustion. Although a second determination was greatly desirable, the material for it was not at hand.

It is interesting to note in this connection, however, that certain bituminous substances have been reported as containing

a much greater percentage of oxygen than the figures in the present case. According to Schrötter* dopplerite contains 43·03 per cent oxygen. Elaterite appears to be associated sometimes with substances of high oxygen content, which makes the amount of oxygen present in the unpurified material run as high as 35 or 40 per cent.

On heating above 100° C. many natural asphalts and "breas" froth very characteristically because of the water contained in them. Inasmuch as no frothing occurs on heating this tar to 150° C. it is concluded that it contains no appreciable amount of water. This cônclusion is supported by the fact that the petroleum ether, chloroform and carbon disulphide solutions are perfectly clear, showing not the slightest turbidity, a circumstance hardly probable if water were present chemically uncombined in the specimen.

As the temperature is raised above 100° C. the tar begins to decompose slowly. At 150° C. the action is very decided. A volume of inflammable gas, large in proportion to the weight of the substance heated, is liberated. This reaction is completed between 200° C. and 250° C. after which but little decomposition ensues until the temperature rises above that indicated on an ordinary thermometer.

An attempt was made to determine the boiling-point of the oily liquid left after such heating. It remained unchanged at 300° C., and, on heating the tube with a small flame, would creep away from the hotter portions without visibly boiling at 360° C.

The substance remaining after heating to 250° C., on cooling, resembles the original tar in appearance. It is, however, no longer completely soluble in petroleum ether. Only about two-thirds are dissolved by this solvent. Most of the remainder is soluble in carbon disulphide but there always remained a distinct residue which could only be dissolved in chloroform. In these solubility relations it resembles ordinary asphalt possessing a large "petroleum-ether-soluble fraction" ("petrolene") and a smaller "asphaltene" fraction soluble in carbon disulphide. The portion soluble only in chloroform is thought by Pecham† to be an indication of "weathering" in those asphalts in which it occurs in appreciable amounts. In this instance it is clearly formed by the action of heat. A combustion of 0·0405 gram of the material heated as described gave 0·1257 gram carbon dioxide and 0·0452 gram water, indicating 84·7 per cent carbon, 12·4 per cent hydrogen and about 3 per cent of oxygen and sulphur. These percentages correspond with the figures given by asphalts generally on combustion.

* Wien., Akad. Ber., 285 (1849).

† Jour. Franklin Institute, No. cli, pp. 114–124 (1901).

In short, this material can not be differentiated from ordinary natural asphalt in any way. It would appear that the tar as it exists in the fossil has not been completely bituminized, since it apparently contains considerably more oxygen than bituminous bodies generally possess. On heating to 150° C. the transformation is completed and the resulting product is in all respects a typical asphalt. The ready decomposition of the tar and the entire change in its composition and nature after being heated to 150° C. offer evidence that the specimen has never been heated to this temperature previously.

When the asphalt thus formed is heated to a dull red heat more gas is liberated, doubtless due to "cracking" of the high-boiling oils constituting it, and a residue resembling coke is left.

The Matrix.

The matrix in which the egg is embedded varies from a little less than half an inch to nearly an inch in thickness, and consists of a fine-grained gray limestone, readily effervescing when treated with dilute hydrochloric acid. A quantitative analysis was deemed unnecessary. Qualitatively examined, it gives slight tests for iron, aluminum, silicic and boric acids, the relative amounts being in the order named. Magnesium is present in larger quantity. No tests for sulphates, phosphates or chlorides were obtained. In short, the matrix seems to be a limestone of considerable purity. It shows no geological evidence of metamorphism whatever.

In an indentation in one side of the limestone is a small deposit of very fine hard clay, indicating that at some time during its history the fossil embedded in its limestone capsule has been buried under such conditions as to allow the formation of clay about it.

On being fractured, especially when crushed in a mortar, the limestone gives off the peculiar fetid odor supposed to be due to the presence of organic matter. On dissolving in hydrochloric acid an odor similar to that produced when iron and zinc are treated with acids becomes apparent, and a slight greasy scum is evident on the surface of the liquid when in a test-tube. The intensity of these phenomena is not greater than is observed frequently in limestones containing no appreciable amounts of organic matter.

In order to ascertain the nature and amounts of this organic matter present, a piece of the matrix weighing about 10 grams was extracted with petroleum ether to remove the tar filling the pits and covering the inner surface. The piece was then finely powdered and extracted again with boiling chloroform. Upon evaporation, from 9·7380 grams of the matrix 0·006 gram of tar similar to the other tarry material was obtained.

To ascertain whether this tar could be extracted from all sections of the matrix or was found alone in those layers nearest the center, pieces of the limestone from three different sections of the outer layers of the matrix, removed as far as possible from the fossil itself, were powdered and extracted similarly but no weighable residue was obtained from any portion. This indicates that the carbonaceous material soluble in chloroform is not distributed evenly throughout the matrix but is confined to the layers in the immediate neighborhood of the tar-filled fossil. Since the amount of tar extracted from the matrix previously mentioned represents only about 0·06 per cent of the weight of the limestone, inasmuch as the extracted material seems identical with the tar found inside the egg and covering the shell, it is believed that this amount was some of the same material from inside the shell which was not extracted by the solvent previous to grinding. Therefore it is believed that the matrix as a whole contains no carbonaceous matter of a bituminous nature.

To ascertain whether the matrix contains appreciable amounts of carbonaceous matter which will become bituminous on heating, about 10 grams of the limestone were heated in a hard glass tube in an atmosphere of carbon dioxide. The products of the ignition were passed through a freezing mixture to collect any liquid distillate and the gas was collected over potassium hydroxide solution. On heating beyond the limit of a thermometer reading to 360° C., only 3^{ccm} of gas were collected. On withdrawing the thermometer and raising the temperature to dull redness, 7^{ccm} more gas collected during a half-hour's heating, when the hard glass tube fused and blew out. Nothing but a drop or two of water condensed in the freezing mixture. Thinking that the gas which had collected might be air a taper was applied, when a slight explosion ensued, showing that a part only of the 10^{ccm} of gas was combustible.

Assuming the combustible gas to have been entirely methane, 10^{ccm} would weigh 0·007 gram. In reality the amount of combustible gas could not have been half this figure, since it exploded on the application of a taper. Since extraction of the heated limestone with boiling carbon disulphide left no weighable amount of material, it is safe to say that the matrix does not contain more than 0·02 or 0·03 per cent of carbonaceous matter of a pyrobituminous nature.

On examining the limestone left in the tube it seemed to be somewhat lighter in color. On being sprinkled on red litmus paper moistened with water, the color changed to blue, showing that the temperature had been sufficiently high to "burn" some of the limestone in an atmosphere of carbon dioxide and make it caustic. On being treated with acids it no longer

liberated the fetid odor previously mentioned, but left behind small amounts of a very voluminous insoluble black residue, largely carbonaceous, which from 1 gram of the ignited material did not exceed 0·0006 gram. Since the analysis of many "stinking" limestones, barites, cherts and quartz failed to show the presence of carbonaceous matter, it seems safe to say that the limestone composing the matrix by which the egg was surrounded does not contain as much as 0·1 per cent of carbonaceous matter. Furthermore, this small amount is of a pyrobituminous rather than a bituminous nature, requiring a temperature of approximately 800° C. to decompose it into gaseous decomposition products.

Evidence as to Origin.

In seeking for an adequate source of the tar present within the egg the most satisfactory answer may be obtained by the method of exclusion. The specimen was found in a region from which very few deposits of bituminous substances have been reported. It is necessary to assume that the colemanite came in from outside in solution, percolating through the matrix. The detection of boric acid in the limestone is, therefore, what would naturally be expected. If the very insoluble tar had come in through the matrix in a similar manner, it would be highly reasonable to expect to detect its presence, also, in the matrix. No tar was found except in the layer immediately in contact with the shell, where all evidence goes to show that the movement has been in the contrary direction, i. e., from within toward the exterior. In short, no evidence has been discovered to indicate that the tar came in from without.

On the other hand, there is considerable evidence to indicate that the tar could hardly have come in from an outside source. The tar is entirely too viscous to have come in its present condition through the solid matrix surrounding the egg. It is possible that it might have passed through the matrix dissolved in a lighter solvent which has since disappeared. In this case, after entering the egg, as the solvent evaporated the solution must have concentrated and tended to collect in one deposit on the bottom of the cavity. But there are several deposits of the material within the eggshell, some being diametrically opposite the main body of material which is assumed to have collected on the floor of the cavity. Similarly, the distribution of the tar inside the shell, coupled with its ready decomposability when heated, forbids the possibility of its having entered from without in the gaseous state. Considering the properties of the tarry material, there seems to be no reasonable possibility that it could have come in from an

external source, and have been deposited as it now is inside the eggshell.

Evidence of an adequate source for the tar in the limestone in which the fossil was embedded seems to be entirely wanting. There is no bituminous matter in the matrix, neither is there an appreciable quantity of any pyrobituminous material. Moreover, the ready decomposability of the tar with the formation of a product insoluble in petroleum ether indicates clearly that the temperature of its surroundings could never have been as high as 150° C. But at this temperature there was no evidence at all of pyrobituminous material, since the small amount of gas produced was liberated only at a red heat.

Considering the indubitable evidence that the tar was present before the colemanite came in, the small amount of bituminous matter present inside the shell, rather than an egg filled full of the material, is not without its significance.

Considering the highly fragile nature of an egg and the perfect state of its preservation, the conclusion that it was encased very soon after it was laid seems inevitable. This must mean the inclusion of its natural contents.

There is no reason to suppose that the egg of any previously existent bird, the shell of which is so similar to present day specimens as to be indistinguishable even under the microscope, would differ materially in the chemical nature of its contents.

In the eggs of the various families of birds which have been analyzed, there is but a slight variation in the relative proportions of the constituents, a difference not sufficient to invalidate the present considerations. The average composition of the edible portion of ducks' or geese's eggs may be taken as 15·5 per cent protein and 14·5 per cent fat. Very probably these figures closely represent the composition of water birds' eggs as a whole. The cubical contents of the fossil egg is 49^{ccm}. Assuming the specific gravity of its natural contents to have been 1 (it is usually a trifle greater), there would be about 7·5 grams of fat and somewhat more of dry protein. Assuming that the protein would lose all of its nitrogen and sulphur as ammonia and hydrogen sulphide or their equivalents, and that part of its carbon would disappear as the monoxide or dioxide or their equivalents, 40 per cent of the dry weight of protein would still remain if these decompositions took place without the intervention of oxygen from without. Under the same circumstances more than 90 per cent of the fat would still remain. There is, of course, the probability of a decomposition resulting in the formation of methane, but of the magnitude of this reaction no inferences can be drawn or allowances made. The assumption of

5 or 6 grams of residue from the contents of an egg of the size of the present specimen is not, therefore, unduly large.

It is difficult to estimate closely the amount of tar present in the fossil because of its varying distribution. The total quantity of bituminous matter could not have been more than 3 grams and was probably much nearer 2 grams. This amount might well have been derived from the fat alone. The absence of nitrogen in the bitumen may possible be accounted for by the suggestion that the easily decomposable protein may have entirely disappeared, while the more stable fatty constituents may alone have become bituminized.

The derivation of the tar from the original contents of the egg is, then, entirely possible, and from what is known of the process of bituminization its origin from such a source, under the conditions to which it has doubtless been subjected, is not in the least improbable. In the absence of any evidence to the contrary, therefore, since extraneous sources have been shown to be highly improbable, no reasonable ground seems to exist for doubting that the tar now present in the fossil has been derived from the natural contents of the egg.

Bearing.

After more than seventy years of painstaking investigation from the purely scientific as well as technical sides, the matter of the origin of bitumens is still an open question in many respects. Three entirely distinct theories have been before the world for years, ascribing their origin to three separate and distinct sources. The laboratory investigations of Moissan, especially for the theory of inorganic origin, and of Warren, Daubrée, Engler, Day and Sadtler for the organic side, have made it apparent that the results of experimentation support any theory and that artificial production indicates only the possibilities and not necessarily the realities as to the origin of bitumens.

Furthermore, every case of artificial production of bituminous matter has required a temperature much beyond the ordinary, a condition which an examination of natural deposits seems to render exceedingly improbable. "What geologists would be glad to find in Nature," says Professor Orton,* "as matching to and harmonizing with the facts with which they are obliged to reckon, would be a process in which the products of the organic world are transformed into mineral oil at ordinary temperatures with complete consumption of the substances acted upon so that no carbon residue would be left behind. They would also expect the transformation to be accomplished while

*Bull. Geol. Soc. Am., 9-90 (1898).

the organic matter still retained essentially its original character."

The attempt has been made repeatedly to realize these condition,—to ascertain whether unquestioned evidence could not be obtained to show from what kind of matter natural deposits have actually been derived. Many natural deposits have been carefully examined, but in no case can the evidence be considered as conclusive.

Thus, Wall pronounced the celebrated "pitch lake" of Trinidad to be of vegetable origin because of the remains of vegetation in all stages of transition which are present in the pitch. Jones found in the same pitch unquestionable animal remains; hence an animal origin is not improbable. Later Richardson* examined the "lake" and concluded that the conditions present offer "a far more reasonable basis for the assumption of a volcanic origin."

Fraas observed petroleum oozing from a coral reef in the Red Sea and concluded that the coral polyps are to-day being changed into bitumen. Binney noticed the same phenomenon about a peat bog in England and inferred that peat was being transformed at the present time into petroleum. Both of these are isolated instances. No other known coral reefs or peat bogs show evidence of similar changes, although conditions seem to be identical. Neither occurrence was thoroughly studied to ascertain what evidence there might be for or against the possibility of another origin. Neither instance is to be regarded, therefore, as unquestionable.

The occurrence of bitumen in fossils has hitherto been of no value as a means of furnishing direct evidence as to its origin, inasmuch as investigation proves that the bitumen need not, and often could not, have been derived from the organism with the remains of which it is to-day associated.

The discovery of the present specimen, a fossil egg partly filled with bituminous material, is under these circumstances of scientific value. For while absolute proof cannot be given, the evidence amounts almost to a demonstration that the bituminous substance now present in the egg represents a part of its original organic contents. In the absence of any evidence to the contrary we may accept that origin toward which all the evidence points. This specimen presents, then, one of the very few instances, possibly the only one, in which conclusive evidence is at hand to connect bituminous matter with the original material from which it has been derived by a natural process without abnormal conditions.

The absence of nitrogen from a bitumen material can not be regarded, therefore, as unquestioned evidence of its vegetable

* Jour. Am. Chem. Soc., 7-51 (1893).

origin, neither should the association of bitumen with boric acid be considered as a strong indication of volcanic origin for the bitumen.

University of California, Berkeley, California.

EXPLANATION OF PLATE XVIII.

Figure 1.—Side view of egg.
Figure 2.—Egg in the original matrix.
Figure 3.—Matrix from inner side, showing pits.
Figure 4.—In the matrix, end view.
(All figures natural size.)

Measurements.

Length of egg	62^{mm}
Width " "	40
Circumference (longitudinally)	169
" (transversely)	124
Long diameter of enclosing capsule	120
Average thickness of enclosing capsule	12
Thickness of eggshell	·33

EXPLANATION OF PLATE XIX.

Figure 1.—Fractured surface of the broken egg, showing the contents; *t*, *t'*, and other darkened areas represent the bituminous material; the remainder of the cavity is filled with colemanite. (Natural size.)

Figure 2*a*.—A portion of the eggshell ground down on one side. *s*, corrugated outer surface: *c*, cellular lower layer. (×275.)

Figure 2*b*.—Cross-section of the shell fragment shown in figure 2*a*. *s*, corrugated outer surface; *c*, cellular lower layer. (×275.)

Figure 3.—Outer surface of the shell, showing corrugations of the surface and a large pit filled with bituminous material. (×275.)

Figure 4.—Cross-section of the pit shown in figure 3. (×275.)

Art. XL.—*On the Radio-activity of Natural Waters;* by Bertram B. Boltwood.

The occurrence, in the water of the public supply of Cambridge and the water from a number of other English localities, of a radio-active gas having properties similar to those of the radium emanation, has been demonstrated by J. J. Thomson* and confirmed by E. P. Adams.† Bumstead and Wheeler‡ have also shown that a similar radio-active gas is contained in the city water supply of New Haven, Conn., and in water from a spring at New Milford, Conn. That the waters from the hot springs at Bath and Buxton in England also contain radio-active gases has been demonstrated by Allen and Blythswood,§ who examined the gases given off at the springs and also the gases which escape from the water on boiling. The presence of minute quantities of radium salts in these waters and also in the sedimentary deposits formed at the point of issue, which has been observed by Strutt,‖ is of considerable importance since it has been shown by Rayleigh¶ that the gases which rise with the springs consist in part of helium.

Mention is made by Himstedt** of the occurrence of radium emanation in the waters of the thermal springs at Baden-Baden, Germany, and an examination by Elster and Geitel†† of the sedimentary deposits formed at these springs, has made it evident that these deposits contain radium compounds.

Curie and Laborde‡‡ have recently tested the gases given off at certain mineral springs of European origin and by the waters of these springs on boiling. They examined gases from nineteen different sources, fourteen of which they found to be radio-active. The radio-active properties of the gases corresponded to those of the radium emanation.§§

Radium emanation has also been found to occur in crude petroleum and natural gas, as well as in the air drawn from the ground in a number of different localities.

The object of this paper is to describe a method for the quantitative determination of the radio-active gas contained in a water and to furnish a convenient standard for measurement and comparison; also to offer some experimental evidence as to the origin of the radio-active properties of natural waters.

* Nature, lxvii, 609 (1903); Proc. Cambr. Phil. Soc., xii, 172 (1903).
† Phil. Mag., viii, 563 (1903).
‡ This Journal, xvi, 328 (1903); ibid., xvii, 97 (1904).
§ Nature, lviii, 343 (1903); ibid., lxix, 247 (1904).
‖ Proc. Royal Soc. London, lxxiii, 191 (1904).
¶ Proc. Royal Soc. London, lx, 56.
** Ann. d. Physik, xiii, 573 (1904).
†† Physikal. Ztschr., v, 321 (1904).
‡‡ Compt. Rend., cxxxviii, 1150 (1904).
§§ H. Mache, Physik. Ztschr., v, 441 (1904).

Method of Determination.

The gases dissolved in a water can be conveniently separated and collected by the method described by Reichhardt.* The apparatus as ordinarily constructed is too small for the purpose under consideration and requires certain modifications. It consists (fig. 1) of a vessel *A* made from sheet copper and having a capacity of about 9 liters. The orifice of this vessel, 9^{cm} in diameter, is surrounded by a heavy brass ring, 15^{cm} in outside diameter, to which can be attached by clamps a heavy brass

1

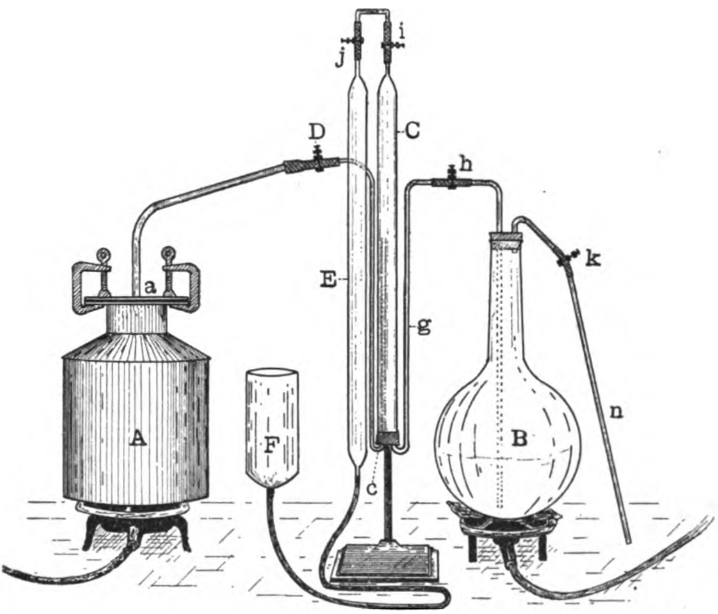

plate *a*, having a block-tin pipe soldered into an opening in its center. A rubber gasket, 3^{mm} thick, between the plate and the ring makes the joint perfectly tight when the clamps (6 in number) are screwed up tightly. A piece of thick-walled rubber tubing carrying a screw-pinchcock *D* connects the tin pipe with the glass tube *c*, which extends to the gas receiver *C*. This latter is 52^{cm} in length and 3^{cm} in diameter and has a total capacity of about 350^{cc}. The tube *c* protrudes about 20^{cm} into *C* beyond the rubber stopper at the bottom. The top of *C* is drawn out into a short, narrow tube and is closed by a rubber tube and a screw-pinchcock, *i*. The tube *g* passes from the bottom of *C* and is joined at *h*, by a piece of rubber tubing carrying a screw-pinchcock, to a glass tube which passes through a rubber stopper and extends to the bottom of the

* Hempel's "Gas Analysis" (translated by L. M. Dennis).

flask *B*. This flask has a capacity of about four liters. Through the stopper which closes it, there also passes a short glass tube attached by a short rubber tube to the glass tube *n*. The end of *n* dips into a good-sized beaker. The contents of *A* and *B* can be brought to boiling by the heat from two large gas-burners placed below the vessels.

In making a separation of gas, the flask *B* is first filled about one-half full of distilled water, which is boiled vigorously for about fifteen minutes. In the mean time the vessel *A* is completely filled with the water to be tested, the cover *a* placed in position and secured by the clamps, the rubber tube *D* disconnected from the tin pipe, and the pinchcocks are all opened. At the end of the 15 minute interval the pinchcock *k* is closed, when the pressure of the steam in *B* will force the boiling water from *B* into *C* and the tubing connected with it. When these are completely filled with the hot water, the pinchcocks *D* and *i* are closed and the cock *k* is opened. The tin pipe attached to *a* is now filled full of distilled water and the rubber tube *D* is slipped over it. The pinchcock *D* is then opened and the gas lighted in the burner under *A*.

The gas burette *E*, filled with distilled water, is connected with *i* by a short piece of capillary tubing, and the screw-pinchcock *j* is opened. As the temperature of the water in *A* approaches the boiling-point, the gas is freely disengaged and, passing through the tube *c*, accumulates in the upper part of the gas receiver *C*. By lowering the balance-receptacle *F* and opening the cock *i* the gas can be transferred from time to time to the burette *E*. The water in *A* is boiled gently for about 20 minutes. By a proper regulation of the pinchcock at *k* and the burner under *A* the pressure within the apparatus can be so regulated that the height of the water column in *C* is about 10 centimeters. The pinchcock at *h* is used in emergencies when the water in *A*, having become slightly superheated, tends to boil too vigorously and the excess of steam threatens to force the accumulated gas out of *C* into *B*. In such cases the cock *h* is closed, the gas under *A* turned off and the cock *i* opened, permitting the excess of vapor to pass over into *E*.

Since natural waters almost always contain an excess of carbon dioxide gas, a few cubic centimeters of a strong solution of sodium hydroxide is added on introducing the sample into *A*. This combines with the free carbon dioxide and reduces the volume of gas set free on boiling.

After all the gas obtained from a given sample of water has been transferred to the burette *E*, it is introduced into an air-tight electroscope. This operation is carried out in the following manner:

The air in the electroscope is exhausted until the pressure is about one-half atmosphere. To one of the stopcocks of the electroscope a small T-tube is attached by a short length of rubber tubing. The branch of the T-tube connected with the rubber tube contains a filling of granulated, anhydrous calcium chloride held between plugs of cotton wool. The rubber tube *i* of the gas burette is slipped over another branch of the T-tube, and the third branch is closed by a short rubber tube plugged with a glass rod. The pinchcock *j* is first opened and then the stopcock of the electroscope is opened, so that the gas is drawn very slowly into the electroscope. When the water in the burette has risen to the junction of the side tube, the pinchcock *j* is closed and the plug removed from the side tube, permitting the external air to pass into the electroscope and sweep with it any of the gases from *E* remaining in the tube and connections. When the atmospheric pressure is established in the electroscope the stopcock is closed and the apparatus disconnected.

In the tests which will be described later in this paper the average volume of gas obtained was about 150^{cc}. The capacity of the electroscope used was about 530^{cc}, so that under the conditions which have been described about 100^{cc} of atmospheric air swept through the connecting tubes before the normal pressure was established in the interior of the electroscope.

The activity of the gas from the water was measured in the electroscope, which has been described in a previous paper.* The gold leaf was charged by a battery consisting of 216 small, lead storage cells, at a potential, therefore, of about 432 volts. The positive terminal of the battery was earthed and connected with the case of the instrument; the negative terminal was connected with the top of the rod supporting the gold-leaf. The normal air-leak of the instrument was low and quite constant, and was equal to approximately 0·012 division per minute. The readings obtained with each measurement of gas were corrected by this quantity.

Because of the initial rise in the activity when the emanation is first introduced into the electroscope, due to the formation of "emanation X" on the walls of the vessel, the rate of leak at the end of three hours was taken as the measure of the activity.

Standard.

One of the most important points in the measurement of the radio-activity of the gas contained in a water is that the results shall be given in the terms of some standard which will permit the direct comparison of the results obtained by different experimenters. In the investigations conducted by

* This Journal, xviii, 97 (1904).

Curie and Laborde the standard adopted is the quantity of emanation produced by one milligram of pure radium bromide in one second. Such a standard would suffice for all immediate needs if it were not for the fact that it is impossible for others to obtain at present even small quantities of radium bromide of known and established purity. Other investigators have adopted the plan of expressing the activity in terms of the number of ions produced per second in a volume of one cubic centimeter. This is difficult to determine with accuracy and its indirect calculation is uncertain.

The standard here suggested and employed is the quantity of radium emanation set free when a known weight of uranium in the form of a natural mineral is dissolved in a suitable reagent.* The mineral which has been used is a pure uraninite from North Carolina. It was dissolved in aqua-regia, the solution diluted with water and the gas removed by boiling. The details of the operation follow:

The sample of uraninite was finely pulverized in an agate mortar. A portion on analysis was found to contain 82·46 per cent of uranium. A quantity of the pulverized mineral equal to 0·0121 was weighed out into a small tube made by cutting off about 4^{cm} of the bottom of an ordinary glass test-tube. The tube was lowered by means of a short piece of common thread into a flask of about 100^{cc} capacity, which had been previously filled about one-half full of distilled water. A rubber stopper with which the flask could be closed carried a glass tube, which could be pushed through the stopper until the lower end was just above the surface of the water in the flask. Beyond the stopper the tube was bent at a right angle. The stopper was placed very loosely in the neck of the flask, the tube which it carried being at the same time inserted in the top of the tube containing the mineral. On releasing the end of the thread at the right moment this dropped into the flask, leaving the tube floating on the water and supported in an upright position by the fixed tube within it. The rubber stopper was then tightly inserted in the neck of the flask and about one cubic centimeter of aqua-regia was introduced into the tube containing the mineral, a small pipette with a long, thin, capillary tube being used for this purpose.

The open end of the tube was then connected with the rubber tube *D* (fig. 1), the vessel *A* having been removed. The pinchcock *D* was opened, the flask and contents were warmed gently and the uraninite was dissolved. When the solution of the mineral was complete the tube extending into the flask was drawn out through the rubber stopper until the opening was just below the stopper. This permitted the tube containing

* This Journal, xviii, 97 (1904).

the solution of the mineral to fall on its side and fill with water. The contents of the flask were now boiled for about 20 minutes, a few snips of platinum foil having been placed in the flask to prevent bumping. The gases which accumulated in the tube *C* were transferred to the gas burette *E*, allowed to stand for 15 minutes and then introduced into the electroscope. The water in the flask *B*, the tube *C* and the gas burette *E* contained a little sodium hydroxide to absorb any chlorine which might be produced in the reaction. The time which transpired from the boiling off of the gas to its introduction into the electroscope (about 30 minutes) was sufficient to reduce the activity of the thorium and actinium emanations also present to a negligible value.

The rate of leak as determined at the end of three hours was taken as the basis of calculation, and was considered as equal to the activity of the radium emanation associated with 0·0100 gram of uranium. This leak was equal to 1·76 division per minute. A fall of the gold-leaf equal to 0·001 division per minute was therefore equivalent to $5{\cdot}68 \times 10^{-6}$ grams uranium.

Calculation of Initial Activity.

In most cases it is either impractical or altogether impossible to carry out the measurement of the activity of the water at the source of the spring. A certain length of time, either a few hours or several days, must elapse between the time of collection of the sample and the time that the test is conducted. Since it is highly probable that the activity of most, if not all, radio-active waters is due *chiefly* to dissolved radium emanation, this activity will become regularly less on standing. The decay of the radium emanation will follow the simple exponential law expressed by the equation:

$$I = I_0 e^{-at},$$

in which I represents the activity after the interval *t*, I_0 the initial activity, *e* the base of the Napierian system of logarithms and *t* the elapsed time expressed in hours. The value of the constant *a* is 0·00724 as determined by Curie, 0·00778 as determined by Rutherford and Soddy, and 0·00744 as determined by Bumstead and Wheeler.*

The initial activity of the water can therefore be calculated from the observed value of I. A convenient form of the equation is then

$$I_0 = Ie^{at}.$$

Radium Salts in Solution.

The presence or absence of radium salts in solution can be demonstrated by boiling about 10 liters of the water, a little

* This Journal xvii, 97 (1904).

acetic acid being added to prevent the precipitation of carbonates. After boiling, the water is allowed to stand for several hours in contact with the air and is then introduced into a bottle and tightly sealed. The capacity of the bottle should be such that the water completely fills it, leaving only the smallest possible air space below the stopper. The water is then allowed to stand for a sufficient length of time (say 16 days) and is then boiled again in the apparatus shown in fig. 1. If radium salts are present in the water, the gases given off on this second boiling will contain the accumulated radium emanation, and the relative quantity of radium present can be calculated from the observed activity of the gas.

Radio-active Waters.

A considerable number of samples of radio-active waters have been examined by the method herein described. Data on only three of these is at present available. The sources of these three samples were the following:

No. 1. Water from a spring at Windham, Me. This spring is known as the "Maine Granite Spring," and is stated to issue from a granite and sandstone formation, to have an estimated flow of 100 gallons per minute and to have a temperature of 43° Fahr. throughout the year. This sample was tested four days from the time of collection and was obtained through the courtesy of Prof. Chas. F. Mabery.

No. 2. Water from a spring in one of the public parks of the city of New Haven, known as "Cold Spring." The formation immediately adjacent to the spring is red sandstone, and the temperature of this spring on September 5, 1904, was 52° Fahr. The flow is small.

No. 3. Water of the city supply in New Haven, drawn from the pipes in the laboratory.

The radio-activity of the gases from these samples is given in the table which follows:

TABLE.

Sample No.	Liters taken.	Leak measured.	Leak per liter.	I.	I_0.	
1	8·9	9·91	1·11	63·22	128·6	calculated.
2	8·9	0·61	0·068	....	3·9	measured.
3	8·9	0·0036	0·0004	....	0·025	"

The leak is expressed in divisions per minute, the values of I and I_0 are expressed in terms of grams uranium $\times 10^{-4}$ per liter of water. The value given for No. 3 is the mean of three separate determinations. The value of the constant, a, employed in the calculation was that determined by Bumstead and Wheeler.

Samples Nos. 1 and 2 were tested for radium salts in solution with negative results. It has been shown by Bumstead and Wheeler that no radium salts are present in the New Haven water (No. 3).

The radio-active properties of the gases from the first two samples were carefully examined and were found to correspond with those of the radium emanation. The activity fell to one-half in approximately four days and the rate of decay of the excited activity agreed with that of the "emanation X" from radium.

Origin of the Radio-active Properties.

The following experiments were carried out with a view to determining the possible source of the radio-active properties in the waters.

A quantity of uranium minerals was pulverized in an iron mortar and passed through a 100-mesh sieve. The minerals consisted chiefly of uranophane, but contained also some gummite, autunite and a small quantity of uraninite. The greater quantity of the material represented the final decomposition-product of uraninite when subjected to the action of percolating waters. The material taken weighed 80 grams. It was placed in a flask and about 500^{cc} of distilled water were poured over it. The contents of the flask were mixed thoroughly and allowed to stand, with occasional shaking, for about twenty-four hours. Some of the mineral was in such a fine state of division that the water remained very turbid after standing undisturbed over night.

The mineral was filtered off on a Buchner filter and the filtrate was boiled (to expel emanation). The water was cooled, introduced into a two-liter bottle with glass stopper, diluted with distilled water until the bottle was quite full and the stopper tightly inserted. The water was allowed to stand for four days, and the gases which it contained were then boiled off and tested in the electroscope. The activity of the gas was equivalent to 0·016 division per minute.

After filtering off the water as described above, the powdered minerals were washed twice with distilled water and the excess of water removed by suction. 100^{cc} of cold distilled water were then poured over the mass on the filter and drawn through it, this filtrate being separately collected. The filtrate was allowed to stand in an open beaker for one-half hour and was then boiled, the gases given off being collected and introduced into the electroscope. The leak at the end of three hours was 0·240 division per minute.

The mineral powder on the filter was washed back into the

flask and about 500^{cc} of water added. The water was boiled for three hours. The mineral was then filtered off and the filtrate boiled for one-half hour. The filtrate was diluted, sealed up for four days and then boiled again. The gases given off were tested for radio-activity in the electroscope and the observed leak was 0·034 division per minute.

About 80 grams of the same mineral mixture but in coarser powder had been shut up in a flask for about eight days. A sample of the gas in the flask withdrawn and separately tested showed that the total accumulated emanation in the flask had an activity equivalent to approximately 1700 divisions per minute. The gas was drawn from the flask into a 4-liter bottle by allowing the water with which the bottle was filled to run out until only about two liters remained. The bottle was then closed and shaken vigorously for about five minutes, and was then allowed to stand undisturbed for about thirty minutes. Water was then run into the bottle until all of the gas was displaced, the gas being collected in a second bottle (see below). Care was taken to remove any small bubbles of gas adhering to the neck of the bottle, and the water it contained was then introduced into the boiling can. The gases were boiled out of the water and tested in the electroscope. The activity of the gas obtained was equivalent to 80 divisions per minute.

The second bottle mentioned above, having a capacity of four liters, was filled one-half full of the gas from the first bottle, the gas being introduced at the top, while the water with which it was at first filled was permitted to flow out through a tube reaching to the bottom. Care was taken to avoid any agitation of the water and the gas was allowed to stand in contact with it for about two hours. The bottle was then completely filled with water by means of a tube reaching to the bottom and the gas was displaced. The activity of the gas obtained from the water on boiling was equivalent to a leak of 0·40 division per minute.

Summary.

From the results of these experiments it is apparent that by the action of cold, pure water on the uranium minerals used only a very slight trace of the radium contained in them is dissolved. The action of hot water is only slightly greater than that of cold water. Even brief contact with uranium minerals can impart to water very marked radio-active properties due to dissolved radium emanation. Water can also acquire very readily measurable quantities of radium emanation by simple contact with gaseous mixtures containing the emanation.

On applying these data to the occurrence of natural radio-active waters, it would seem as if all the observed facts could be readily explained. An extremely minute trace of uranium minerals in the rocks and soil through which the waters percolate in their underground passage would be sufficient to impart to them radio-active properties, which could be readily detected by the sensitive method at command. It can be anticipated that waters which rise through strata containing appreciable quantities of uranium minerals will be found more highly radio-active than any which have thus far been described. The results obtained from the examination of waters from springs in well-known uranium localities can be looked forward to with interest.

In those cases, at Bath and at Baden-Baden, where the waters have been found to carry traces of radium in solution, it can safely be assumed that the decomposing action of the waters due to their high temperature is still further increased by the pressure and by the fact that they contain various chemical substances in solution. These latter, while they promote the decomposition of minerals, may also retard the removal of the radium through the formation of insoluble sulphates, phosphates, etc. The fact that these waters on reaching the surface almost immediately deposit the greater portion of their radium is indicative of the difficulty with which that element is retained in solution.

In view of the extraordinary sensitiveness of the radio-active test for the radium emanation, it is very surprising that samples of gases from four of the springs examined by Curie and Laborde were found by them to be quite inactive.

139 Orange St., New Haven, Conn.,
October 11, 1904.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Action of Radium Emanations on Diamond.* — Having previously shown that diamonds, when exposed to the impact of radiant matter in a high vacuum, become blackened from a superficial coating of graphite, Sir William Crookes has recently experimented upon the action of the rays from radium upon these gems. Two diamonds having the same pale yellow color were selected, and one of them was kept for a fortnight close to a quartz tube containing 15 mg. of radium bromide sealed *in vacuo.* Comparison of the exposed diamond with the one not exposed showed no appreciable difference in color, and the same result was obtained after six weeks of exposure. The diamond phosphoresced brightly and continued to glow during the whole period of the experiment. The previously exposed diamond was now put inside a tube with radium bromide, the salt touching it on all sides, as it was thought possible that a screen of quartz might interfere with the passage of emanations which would act on the diamond. After a continuation of this exposure for seventy-eight days, the diamond had a darker appearance than the one reserved for comparison, and it showed a bluish green tint with no apparent yellow color. It thus appears that radium emanations, which darken glass in a marked manner, and quartz to a slighter extent, are also capable of darkening the diamond. The exposed diamond was now treated for ten days with mixtures of the strongest nitric acid and potassium chlorate, for the purpose of testing for a superficial formation of graphite. It was evident that graphite had been present, for the diamond lost its dull surface color and was as bright and transparent as the other stone, but its tint had changed from yellow to a pale blue-green.

The conclusion is reached that the radium emanations have a double action on the diamond. The β-rays (electrons) exert a superficial darkening, converting the surface into graphite in a manner similar to, but less strongly than, the more intense electrons in the cathode stream. But the alteration of the body color of the stone by emanations which are obstructed by the thinnest film of solid matter, even by a piece of thin paper, is not so easy to understand. It is believed that the alteration of color is a secondary effect, connected with the extremely phosphorescent state of the diamond during its exposure. It is not difficult to suppose that a chemical as well as a physical action may result. If the yellow color is due to iron in the ferric state, a reduction to the ferrous state would account for the change of color to a pale blue-green. This alteration of color may be of commercial importance in treating "off color" stones.

After the exposed diamond had been treated for ten days with the acid mixture, it was carried about with its unexposed com-

panion for about twenty-five days, and then both were laid together on a sensitive film for twenty-four hours. On development, the exposed diamond was found to have impressed a strong image on the film, but only a faint mark could be seen where the other stone had been. A repetition of the experiment confirmed the result.—*Chem. News.* xc, 1. H. L. W.

2. *Radio-active Lead, Radio-tellurium, and Polonium.*—DEBIERNE has arrived at the conclusion that the radio-active lead of Hofmann and Strauss and the radio-tellurium of Marckwald are identical with M. and Mdme. Curie's polonium. The radiation of polonium is distinct from that of uranium, thorium, radium and actinium, and consists entirely of the almost non-penetrating α-rays, which are only slightly affected by a magnet. The radio-active substances which accompany bismuth, lead, and tellurium are all precipitated from acid solutions by hydrogen sulphide, and they have all been derived from pitchblende.

Having at his disposal a large amount of the residues from the extraction of radium, Debierne tried to obtain ratio-active lead. The lead nitrate obtained had a radio-activity only about twice that of uranium. Recrystallization of this nitrate was not effective in concentrating the radio-active substance, but when a large excess of hydrochloric acid was added to a concentrated solution of this nitrate, lead chloride crystallized out, leaving nearly all the radio-activity in solution. By repeating this operation several times the non-active lead chloride was eliminated, and the greater part of the activity was concentrated in a small quantity of matter. This portion, consisting chiefly of lead, was purified from small traces of copper and iron, and then transformed into nitrate. Upon adding the concentrated, slightly acid, solution of this nitrate to a large quantity of water, a very slight precipitate of basic bismuth nitrate was formed, which contained nearly all the radio-activity, and corresponded to very active poloniferous bismuth. The active matter thus obtained also showed all the properties of radio-tellurium; its solution gave an active precipitate with stannous chloride, and an extremely radio-active coating upon a thin piece of metallic bismuth.

It is thus seen that the same radio-active substance shows successively properties characteristic of radio-active lead, polonium, and radio-tellurium. The conclusion to be drawn is that there is no distinction between these three bodies, and it is evident from these experiments that a radio-active substance cannot be identified by chemical reactions, since analytical separations merely cause it to be shared among the different fractions. The only certain test is the nature of the radio-activity, and the identity of the radiations given by polonium, radio-active lead and tellurium would in itself predict the results that have been reached.

Circumstances were such that the lead nitrate used in these investigations was kept for three years before the work was completed. During this time it retained all of its feeble activity, although samples of polonium prepared from it gradually lost

this property. The author believes that the constancy of the activity must depend upon external conditions which it will be very important to determine, and he suggests the possibility that under certain conditions the activity of other substances, such as uranium, thorium, radium, and actinium, will diminish and disappear in the same manner as that of polonium.—*Comptes Rendus*, cxxxix, 283. H. L. W.

3. *Condensation of Helium and Hydrogen by Charcoal.*—As a continuation of his studies on the condensation of gases by charcoal,* SIR JAMES DEWAR has obtained some interesting results with hydrogen and helium. Two discharge-tubes, provided with small condensers containing 1 or 2 g. of wood charcoal were filled, one with hydrogen and the other with helium at atmospheric pressure. The little charcoal condensers were now plunged into liquid hydrogen, with the result that the vacuum became so high that no electric discharge would pass in the tube filled with hydrogen, while in the tube containing helium the vacuum was high enough to obtain the phenomenon of phosphorescence under the action of the discharge. Two similar tubes containing helium from different sources were then subjected to the action of liquid hydrogen boiling under exhaustion, which produced a temperature of 15° absolute. In each case the vacuum resulting from the occlusion of the helium was so high that a coil giving a spark of 4^{cm} in air had to be used to obtain an intermittent phosphorescent discharge. From comparative experiments with hydrogen and helium it is concluded that the boiling point of helium is about 6° absolute.—*Comptes Rendus*, cxxxix, 421. H. L. W.

4. *Die Riechstoffe;* von Dr. GEORG COHEN. 8vo, pp. 219. Braunschweig, 1904 (Vieweg und Sohn).—This book deals with those organic products—synthetical and natural—that are distinguished by some characteristic odor, particularly those which have found commercial application in the manufacture of perfumes. A great number of synthetical products are described, including alcohols, ethers, esters, aldehydes, ketones, and bases; and the reactions by which each class can be identified are discussed. A part of the book is devoted to tables relating to the numerous ethereal oils; their physical constants and chemical compositions are given, together with the names of the plants from which the oils are obtained. A short discussion of the relation between odor and chemical constitution is also given. The references to patent literature are very full. While the book will be of little interest to the theoretical chemist, it will be of use to the technical chemist who is interested in the manufacture of perfumes. T. B. J.

5. *Volumetric Analysis;* by FRANCIS SUTTON. Ninth edition, revised and enlarged. 8vo, pp. 617. Philadelphia, 1904 (P. Blakiston's Son & Co.).—This standard work on volumetric analysis is so universally known among English-speaking chemists

* See this volume, pp. 290 and 295.

that the appearance of this new edition requires no comment, except the statement that it contains some important changes and additions. H. L. W.

6. *Emanation of Radium.* — Sir WILLIAM RAMSAY from a careful study of this emanation concludes that it behaves like an ordinary gas resembling the gases of the argon family. It is luminous and obeys Boyle's law. A table of wave lengths of its spectrum is given. The gas is probably monatomic with a density of about 80 and an atomic weight of 160. Its electrons cannot be made to penetrate other bodies. The name *Exradio* is proposed for this gas.— *Comptes Rendus*, June 6, 1904, pp. 1388–1394. J. T.

7. *Emanations—Radiations.*—BERTHELOT suggests that surface films of volatile substances may account for many of the observed phenomena of radio-activity. In this connection the smell of metals is significant.— *Comptes Rendus*, June 20, 1904, pp. 1553–1555. J. T.

8. *Conduction of Electricity through high Vacua.*—Hon. R. J. STRUTT believes from his experiments that, even in high vacua, there is a loss of electricity from a charged body, in presence of the α-rays, independent of traces of residual gas. A rod of bismuth was made radio-active by a deposit of radio-tellurium which emitted α-rays only. The rod was attached to an electroscope. The exhaustion was pushed to the degree that no discharge could be forced through a Röntgen tube connected with the apparatus. The leak seemed to be distinct from that which is due to the ordinary ionization of gases. The author believes that the leak results from the particles torn off from the bismuth by the issuing α-ray. No details are given in regard to the character of suspension of the rod.—*Phil. Mag.*, Aug., 1904, pp. 157–158. J. T.

9. *Negative Ions from Heated Metals and Oxides.* — Many observers have studied the formation of positive or negative ions on heated metals. A. WEHNELT has shown that not only metals but a large number of metallic oxides possess the same property and to a much higher degree than the metals. He continues his investigation in this article and sums up his results as follows :

If platinum foil is covered with the oxides of the earth alkali (Ca, Ba and Sr) the cathode fall of potential is much lessened, from the numerous negative ions which are emitted. It was found at atmospheric pressure that negative ions issued even at a dark red heat from the oxides, while pure platinum held negative ions even at a very high temperature. In a vacuum the oxides and also pure platinum emitted negative ions, the number of which increased with the temperature. With the oxides the number of ions was 1000 times greater than with platinum. Calculation showed that the negative ions per volume-unit of the metallic oxide are 100 times greater than the number of the molecules in the same volume, so that one must assume that to each molecule of the oxide numerous negative ions are combined. The lessen-

ing of the cathode fall when glowing metallic oxides are used is due to emission of negative ions. By means of this property of emission very strong currents can be sent through a gas even at low pressures.—*Ann. der Physik*, No. 8, 1904, pp. 425–468.

J. T.

10. *Electro-chemical Equivalent of Silver.*—Determinations of this constant has been made by the following observers:

Mascart	0·011156
F. and W. Kohlrausch	0·011183
Lord Rayleigh and Mrs. Sidgwick	0·011179
Pellat and Potier	0·011192
Kahle	0·011183
Patterson and Guthe	0·011192
Pellat and Leduc	0·011195

The last determination with, it is claimed, more accurate determinations of the horizontal intensity of the earth's magnetism, the strength of the electrical current and the time, has been made by G. Van Dijk and J. Kunst, who have obtained the value

$$a = 0,\ 0111823 \pm 0{\cdot}0000004 \text{ (m.F.)}$$

From the agreement of observations, this result is claimed to be accurate to $\frac{1}{10,000}$.—*Ann. der Physik*, No. 8, 1904, pp. 569–577.

J. T.

11. *Electric Effect of Rotating a Dielectric in a Magnetic Field.*—According to Maxwell's Electromagnetic Theory, an electromotive force should be induced in a dielectric and its amount—according to Lamor and Lorentz—should be $(1-K^{-1})$ times that in a conductor, K being the permittivity of the dielectric. H. A. Wilson has shown the existence of this effect by rotating a hollow cylinder of ebonite in a magnetic field, parallel to the axis of the cylinder, with suitable conducting brushes, the results of the experiment were as follows :

(1) A radial electric displacement, is produced in the dielectric when it is rotated in a magnetic field parallel to the axis of revolution.

(2) The direction of the displacement is the same as is produced in a conductor.

(3) The displacement is proportional to the magnetic field and to the rate of revolution.

(4) The amount of the displacement agrees with that calculated on the assumption that the induced E.M.F. in the dielectric is equal to that in a conductor multiplied by $(1-K^{-1})$.—*Proc. Roy. Soc.*, June 22, 1904, pp. 490–492. J. T.

12. *A Radio-active Gas from Crude Petroleum.*—E. F. Burton shows that fresh crude petroleum contains a strongly radio-active gas similar in its rate of decay and in that of the induced radioactivity to the emanation from radium and to the emanations obtained by various experimenters from mercury and from certain waters fresh from the earth. This radio-active gas decays approximately according to an exponential law, falling to half

value in 3·125 days. It produces an induced radio-activity, whose rate of decay is such that it falls to a half value in about 35 minutes. There are indications of the existence in crude petroleum of slight traces of a radio-active substance more persistent than the radium emanation.—*Phil. Mag.*, October, 1904, pp. 498–508.

13. *Absorption of Water Vapor in the Infra-red Solar Spectrum.*—F. E. FOWLE, Jr., in No. 1, vol. II, of the Quarterly issue of the Smithsonian Miscellaneous Collection, details the results of a bolographic study, made at the Smithsonian Astrophysical Observatory, of the absorption of water vapor in the infra-red region of the solar spectrum. It is shown that "the selective absorption of water vapor, within the range of densities observed, seems to depend only on the amount of the absorbent present and is well expressed by Bouguer's formula. In other words, the absorption produced by a given quantity of water in the form of vapor, is the same whether the path is great through a small density or vice versa. Considering successive bands, for example 0·81μ, $\rho\sigma\tau$, Φ, Ψ, Ω, it may be noted that the selective absorption of water vapor is not greatest like the general absorption at the shorter wave-lengths, but increases as the wave-lengths of the bands increase. It varies from 10 per cent in the more shallow bands near A, at 0·76μ, to nearly 100 per cent in the bottom of Ω at 1·80μ, when only on exceedingly dry days is much indication of energy detected. However, in the separate bands themselves, when the increase in absorption on reaching the bands from the shorter wave lengths side is quite sudden, the absorption then more slowly decreases like the general absorption with increasing wave lengths."

14. *On the Action of Wood on a Photographic Plate in the Dark.* — Continuing his work on the action of various substances upon a photographic plate, W. J. RUSSELL shows that this property probably belongs to all wood, some kinds, however, being much more active than others. The sample of wood must remain in contact with, or at a little distance from, the sensitive plate for a time varying from 30 minutes to 18 hours; the temperature must not be above 55° C. The wood of conifers is very active and gives definite pictures. A section of a branch of Scotch fir gave an excellent picture showing the rings of both spring and autumn growth; the former were very active and produced dark rings in the picture, the latter were inactive. If, as has been suggested, hydrogen peroxide, present in the resin, is the cause of the action, it is necessary to assume that the resin in the dark (autumn) rings is under such conditions that it cannot escape.

Pine wood acted in the same way as the fir; also the spruces, but with them the action is less definite and sharply marked, and in some cases the dark rings were also active. With larch wood the picture is the reverse of that of the fir, the dark rings being active, the light rings inactive. Of other woods, oak, beech,

acacia, Spanish chestnut and sycamore were active, while the ash, elm, horse chestnut and plane wood were comparatively but slightly active. Exposure to bright sunlight for a short time (5 to 10 minutes) served to intensify to a high degree the action of the active parts; this is true of all wood. This increased action lingers for a considerable time; red glass, however, prevents this increase of activity.—*Proc. Roy. Soc.*, lxxiv, 131.

I. Geology and Mineralogy.

1. *U. S Geological Survey.* — The following publications have recently been issued:

Latrobe Folio, Penn., No. 110; by M. R. Campbell. The Latrobe district is in the midst of the Pennsylvania coal area and its general geologic structure and economic importance have long been known. There is, however, little discussion of physiographic history in the Pennsylvania reports, and it is particularly in this regard that the recent work of Mr. Campbell adds to our knowledge of Western Pennsylvania.

The Schooley peneplain is recognized in the summit of Chestnut Ridge. The Harrisburg peneplain, cut in the Schooley plain when the land stood 1200 feet lower than at present, is recognized here as well as in the Monongahela and Susquehanna Valleys. The Harrisburg peneplain is Early Tertiary. A still lower level is described as the Worthington peneplain. The broad valley floor of the Conemaugh, which is such a conspicuous feature between Blairsville and Tunnelton, is found to correspond to similar features on the Monongahela, Youghioheny and Allegheny rivers, and to date from pre-Quaternary times. This feature is described as the Parker strath. The abandoned channels and oxbows of these rivers are believed to be the results of ice dams in early Glacial time, and not connected with the draining of Lake Monongahela as suggested by Dr. I. C. White. The streams of this district flowed directly toward the ice front and with the advent of spring the ice melted first at the head of the stream. There was thus opportunity for many ice dams, temporary, or even continuing through several seasons. This hypothesis accounts for many abandoned channels in Western Pennsylvania, which otherwise are inexplicable.

Zinc and Lead Deposits of Northern Arkansas: by George I. Adams, assisted by A. H. Purdue and E. F. Burchard; with a section on the Determination and Correlation of Formations, by E. O. Ulrich, 115 pp., 27 pls., 6 figs., Professional Paper No. 24. In addition to the economic study of the lead and zinc deposits of northern Arkansas, Mr. George I. Adams presents a sketch on the geologic and physiographic history of that region. A number of faults already noticed by the Arkansas geological survey are described and proof given that they are normal faults and not thrust faults, as considered by Branner. A description is given of the brecciated dolomite

of the Yellville formation. The brecciation is believed to be due to pressure induced at the time of the folding in the Ouachita Mountain Ranges. Movements which resulted in folding and thrust-faulting in the Ouachita Mountains and open folding in the Arkansas Valley region are represented in the southern portion of the Ozark district by brecciation of individual beds without disturbing their horizontal position.

A Geological Reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho; by Waldemar Lindgren. 116 pp. 15 pls. 8 figs. Professional Paper No. 27.—The Bitterroot Valley is one of the most striking typographic features in the western part of the United States. It is two to nine miles broad, runs almost exactly north and south, and is depressed 5,000 feet below the deeply incised Bitterroot Range to the west. The structure of this valley and of the adjoining mountains has been worked out by Mr. Lindgren, and shows some remarkable and unique facts. The depression owes its existence to the normal fault, but the essential feature of this dislocation is the fact that the fault plane corresponds with the schistosity and jointing, so that there is every gradation between the molecular and molar motions, indicating that both result from the same forces. In the sheared zone there is "intimate and inseparable relation between schistosity and faulting." The striated slipping planes of the granite-schists are closely massed, as many as twelve of them sometimes occurring in a thickness of one inch. This locality would seem to be an excellent one to test the divergent views regarding schistosity and jointing. Mr. Lindgren thinks that the observations of the Bitterroot Range confirm the opinions of Mr. G. F. Becker: that there is no essential difference between jointing cleavage and schistosity, that they may both be produced at the same time, and that molecular movement is not necessarily confined to the zone of flowage. The Bitterroot Range forms one of the largest glacial areas known in the Cordilleras. Excellent illustrations of U-shaped valleys, cirques, and various glacial deposits occur throughout the Range.

2. *Baraboo Iron-bearing District, Wisconsin;* by Samuel Weidman. Wis. Geol. and Nat. History Survey, Bull. No. 13, 171 pp., 23 pls., 3 figs. The Baraboo district, Wisconsin, shows an interesting geological series, consisting of pre-Cambrian igneous and pre-Cambrian sedimentary and of Paleozoic strata. The iron ore is hematite developed from original limonite, and it is an interesting fact that the ores showed no surface outcrop but were found by drilling through sandstone and drift. In order to get at the iron ore it was necessary to understand the geological structure of the pre-Cambrian quartzite (Baraboo). A detailed study of the quartzite shows that its structure consists of a double syncline, on the top of which is deposited unconformably Potsdam sandstone. The hypotheses of Irving, and later of Salisbury, are shown not to be in accordance with the facts.

3. *Chemical Survey of the Waters of Illinois;* by A. W. PALMER, 243 pp. 52 pls.—The factors which make for and against a satisfactory water supply of a state and the relation of geologic structure to these factors are emphasized by the recent report of the Illinois Water Survey. A study has been made of the sanitary condition of the waters of lakes, streams, and wells, as shown by 460 analysis. Particular attention has been devoted to the Illinois River during 1897–1902, and it has been found that the waters of that stream, where they enter the Mississippi, contain less organic matter than previous to the construction of the Chicago Sanitary Canal. A chapter on the Geology of Illinois as related to its water supply is written by Professor Rolfe.

4. *Submerged Tributary of the St. Lawrence.*—In the Transactions of the Royal Society of Canada, vol. ix, Section iv, pp. 143–147, H. S. POOLE publishes a chart and description of an ancient river system with headwaters in Pictou County, Nova Scotia, and receiving important tributaries from Prince Edward, Magdalen, and Cape Breton Islands. The river follows closely the ridges of hard rock near shore, and submerged mounds suggest a continuation seaward of the Carboniferous coast terrace. The presence of this river maintaining its characteristic features through several sub-cycles is sufficient to account for the absence east of Pictou and along Cape Breton of the softer members of the Carboniferous series, without assuming fault boundaries.

5. *Sands and Sediments;* by T. MELLARD READE and PHILIP HOLLAND (Proc. Liverpool Geol. Soc., 1903–04, pp. 3–20).—An investigation has been begun to find out whether there exists any relation between the size of the particles or grains of sand and their chemical constituents; also the degree of minuteness to which particles can be ultimately reduced by natural agencies, and how, and in what way this takes place. These investigations, when completed, will indicate in some degree how far purely mechanical sediments may be carried out and deposited in the ocean. An inquiry is also being made into the question of the origin of limestone by the deposition of infinitesimal particles carried out from the land. The investigations so far give "hints of the possibility of deep-sea limestone being formed in an inorganic way."

6. *Palæontologia Universalis.*—The writer desires to call the attention of American Geologists to the fact that this very important work has but 21 subscribers in the United States, while France has 63 and Germany 96. Certainly the geologists and geological libraries of this country are not yet supplied with this publication. Fasciculi I and II have been issued; these contain 97 sheets redescribing and refiguring 46 of the old and little known species.

It is intended to issue annually from 150 to 160 sheets, treating of about 80 species. The annual subcription price is $8.00. Subcriptions may be sent to G. E. Stechert, No. 9 East 16th street, New York City. Those persons or institutions desiring further information regarding this work, with samples of the plates, will

be supplied on application to Professor Charles Schuchert, Yale University Musem, New Haven, Conn. CHARLES SCHUCHERT.

7. *Interferenz-Erscheinungen im polarisirten Licht; photographisch aufgenommen;* von Dr. HANS HAUSWALDT in Magdeburg. Neue Folge, 1904.—The series of eighty beautiful plates contained in this work forms a very valuable aid to the study of the behavior of crystal sections in polarized light, in fact so excellent are the photographic reproductions that, except for the absence of color, the student can learn almost everything from them that he could from the specimens themselves. This work follows the "Interferenz-erscheinungen an doppeltbrechenden Krystalle im convergenten polarisirten Licht" published two years since by the same author, while still further plates are promised in the future. The plan of the series now issued has been made by Professor Liebisch of Göttingen, to whom the work is dedicated; Dr. Siedentopf, of the optical works of Carl Zeiss in Jena, has also contributed materially to the success of the enterprise in various directions. The execution of the plates (by Studders and Kohl of Leipzig) leaves nothing to be desired.

A complete statement of all that is given in this series would require the reproduction in full of the table of contents. The opening plates exhibit the axial figures for several species (calcite, topaz, gypsum, albite) in converging polarized light as modified by the aperture of the condenser (C_1 and C_2 with num. ap. $=0{\cdot}636$ and $1{\cdot}168$ in each case). Then follow a number of plates showing the limiting curves of the complete interference figures in converging light for calcite and quartz under varying conditions.

The influence of the color of the light source is shown for calcite, quartz, cerussite and titanite, wave-lengths of 620–$720\mu\mu$ and 410–$450\mu\mu$ respectively being used in each case. Other plates show the dispersion of the optic axes of brookite for different colors; the effect produced by the combinations of mica plates of Reusch and of Noerrenberg; the interference bands of wedges of birefringent crystals in parallel polarized light; the spectral analysis of the interference colors of sections of birefringent crystals; the anomalous optical characters of beryl and the peculiar phenomena yielded by boracite, leucite, perofskite, also garnet, milarite and other species. Twin structure is exhibited for numerous species; also spherolitic structure; further, the birefringent phenomena called out in glass by rapid cooling and by pressure, and the effect of change of temperature and pressure in the case of crystals of various species. Finally, absorption phenomena are fully illustrated.

This summary will serve to show the great variety of phenomena exhibited by the upwards of three hundred figures of this unique work.

8. *Tableau systematique des Minéraux classés d'apprès leurs propriétés chimiques et cristallographiques;* par P. GROTH. *Traduit de la quatrième édition allemande* par MM. E. JOUKOWSKY et F. A. PEARCE. Avec corrections et additions de l'auteur. Préface

par Louis Duparc. Pp. viii, 188. Geneva, 1904 (Grebel, Wendler & Cie., Éditeurs).—French students are to be congratulated in having placed before them this translation of Professor Groth's admirable work, a work which occupies a unique place in mineralogical literature and which has exerted a great influence upon the progress of the science since the publication of the first edition thirty years since.

9. *An Introduction to the Study of Meteorites, with a list of the Meteorites represented in the Collection of the British Museum of Natural History on January 1, 1904;* by L. FLETCHER. Pp. 109, London, 1904.—The last edition of this guide to the meteorite collection of the British Museum, with its interesting introduction, was issued in 1896. Since that time the collection has increased notably, the total number of specimens recorded at the beginning of the present year being 557.

10. *Manual of the Chemical Analysis of Rocks;* by H. S. WASHINGTON. Pp. 183, 8vo. New York, 1904 (John Wiley & Sons).—The author states that the object of this book is to present to chemists, mining engineers, petrologists and others who have not made a particular study of quantitative analysis, a selection of methods for the chemical analysis of silicate rocks and especially those of igneous origin. There are probably few branches of science in which a greater amount of earnest, well intentioned work has been done in the last twenty-five years, with so much that is inaccurate and of little value in results, as in petrography in the making of rock analyses. They have, in large part, been made by beginners or by those having little skill, experience or knowledge of correct methods, with a corresponding loss of time and effort. A particularly bad feature of the case is, that it is not always evident or possible, contrary to what generally obtains in pure mineral analysis, to determine how inaccurate the results are. In these later years, however, a change has taken place in this respect and as high a standard of analytical excellence is now demanded in petrography as in any other branch of science.

Several causes have contributed to this result, especially the efforts of a number of earnest workers, among whom are to be chiefly mentioned the chemists of the United States Geological Survey as well as the author of this book.

On the other hand it may be said that there are not many things, when one considers the number of elements to be determined and the length of the processes involved, which demand greater skill and experience in analysis from the chemist than that of silicate rocks.

All this makes the appearance of this work a very timely one and it will be henceforth an almost indispensable adjunct to the library of every analytical chemist and petrographer. The author gives in full detail a description of the necessary apparatus, reagents, etc., and of the proper method of selecting material. The analytical processes selected are those which long

experience has shown to be the best, and the methods for carrying them out are so fully described, that with the attentive use of the work, even beginners may achieve good results, while the experienced analyst will find much that is of interest and value in saving time and work. It is well and clearly written and the field has been thoroughly covered. It is to be hoped that its appearance will do much to raise the standard in this field of scientific work. L. V. P.

11. *Notes on the Rocks of Nugsuaks Peninsula and its environs, Greenland;* by W. C. PHELAN. Smith Misc. Coll., Quar. Issue, vol. 45, pp. 183–212. 1904.—The author has made a study of a collection gathered by Professor Schuchert and Dr. David White. The collection embraced types of gneiss, diorite, syenite, peridotite, monzonite, granite and basalt, the latter containing native iron. Detailed petrographic descriptions of these are given and of several, complete chemical analyses were made. The paper adds considerably to our knowledge of the petrography of Greenland and will be read with interest by petrographers. L. V. P.

12. *Ueber den Kali-Syenit des Piz Giuf und Umgebung und seine Ganggefolgschaft;* von F. WEBER. Beitr. zur Geol. Karte der Schweiz Neu. Folge XIV Leif. Bern, 1904, 4°, 176 pp., pl. V.—The rock masses described in this paper lie in the western part of the Aar massive. The main mass of syenite forms a long slender lens in granitic rocks, about 13 kilometers long and bent slightly into an S shape. It is accompanied by dikes of more salic and femic characters. There are also varieties of the main syenite type. All these rocks, under the headings of syenite, aplite, granite porphyry, spessartite and kersantite, have been thoroughly studied and analyzed and the results are here presented, together with discussions of their relationships, origin, and the bearing of these on the general question of differentiation. It is an extended and careful piece of work which adds to our knowledge of local Swiss petrology and contains much of general interest to petrographers. L. V. P.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Harvard College Observatory.*—Recent publications of the Harvard College Observatory include the following :

ANNALS, vol. xlvi, Part II, pp. 121–249, with plates I, II, Observations of Variable Stars made with the Meridian Photometer during the years 1892–1898 ; by Edward C. Pickering. Vol. liii, No. III, pp. 45–73 with plates I, II. The ninth Satellite of Saturn ; by William H. Pickering. This paper gives a most interesting account of the search, begun in 1888, for the supposed ninth satellite of Saturn, and its identification in 1899 on photographs taken the year previous at Arequipa. Later observations have served to determine with accuracy the orbit of Phœbe, as the satellite has been called. It is found to have an eccentricity greater than that of any other planet or satellite and is exceeded

only by a few of the asteroids. The period is 546·5 days and its diameter is estimated at 200 miles. It is thus the largest body discovered in the solar system, exclusive of the comets, since the inner satellites of Uranus were found by Lassell in 1851; it is also by far the faintest object, its brightness being estimated as two magnitudes less than that of Hyperion, which is assumed to be of the 14th magnitude.

Vol. liii, No. IV, pp. 75–84 with four plates. A Study of Eratosthenes; by William H. Pickering. Some paragraphs from this paper are quoted below.

Vol. lvi, No. I, pp. 1–26 with two plates. Distribution of Stellar Spectra.

CIRCULARS: No. 83, Common's 60-inch Telescope; No. 84, Carnegie Grant of 1903; No. 85, The anonymous gift of 1902.

2. *A Study of a Lunar Crater.* — The following paragraphs, which form the concluding part of the "Study of Eratosthenes" by W. H. PICKERING, referred to above, will be read with interest in connection with the recent discussion of the features of the moon (see p. 314 of the October number). The author closes the detailed description of the crater and the changes in it observed by him as follows:

"Summarizing our knowledge so far, we find that there seem to be four canal systems, two large and two small. They are best seen in figure 11. In each there is a prominent lake from which three or more canals diverge in various directions. The largest of these lakes, which we will call I, is situated to the east of the central peaks. Three canals radiate from it. The second largest, which we will call II, is situated on the northwestern slopes of the central peaks. It also has three canals. III, at the extremity of ridge *A*, has four or five canals radiating from it, and a nearly concentric ring, similar to *Solis Lacus* on Mars. IV is a small and very faint lake at the extreme northern end of the floor, from which at least five minute canals radiate. It also is furnished with a somewhat ill-defined dark ring, composed in part of the lakes and canals of systems I and II. I reminds us somewhat of the *Syrtis Major* on Mars and the two large canals or branches which lead into it from the south, and form a rather characteristic Y at certain seasons.

These canal systems seem to be almost entirely independent of the surface configurations. Sometimes the central lake is on a mountain crest like III, and sometimes in the bottom of a valley like I. The canals sometimes, as in system II, descend one slope, cross a valley, and ascend another. They generally appear all at once throughout their whole length, but in at least two instances we have recognized a progressive motion. In one of these cases, *A*, the direction of motion was tangential to the lake III; in the other, *D*, it was radial and towards the lake I. In both cases the motion was down hill. *D* vanished on the ridge before it did on the lower slopes.

A few words may now be said on the chief objection that has been raised to the theory that these changes are due to vegeta-

tion, namely, the lack of water on the Moon. While it is true that water cannot exist in the free state under a pressure that is less than 4·6 millimeters, and while it is also true that no such pressure apparently exists upon the Moon's surface, still there is nothing to prevent water occurring beneath the surface of the ground, retained by the capillary action of the soil. It has been shown by Cameron (Science, 1903, xviii, 758) that water can be extracted by dry soil from a membrane against a calculated osmotic pressure of 36 atmospheres, or about 500 pounds per square inch. Since on the Earth plants can live on moisture which they have in turn extracted from such a soil, there seems no difficulty in understanding how they could live on the Moon, in a soil which could thus retain considerable moisture in spite of the low atmospheric pressure. Indeed if it were possible to conceive of an organism which could absorb its oxygen directly from vegetation, and store it during the lunar night, there is no reason why animal life should be impossible upon the Moon.

That the substance which we have called vegetation is frequently found in connection with deep clefts has already been pointed out by the author, in dealing with the crater Franklin, see "The Moon," page 56. That a dark patch of vegetation sometimes covers an area formerly occupied by ice has been shown in the case of Riccioli in the Harvard Annals, xxxii, 216. Finally, that different areas of vegetation in the same crater may appear and disappear at quite different times has been pointed out in the case of Alphonsus, in the Annals, xxxii, 33. It therefore appears that the various phenomena above described have all been indicated before in visual observations made at this Observatory. Their interest here lies chiefly in the fact that in Eratosthenes they are shown so clearly, and upon so large a scale, that we are now able to photograph them. We are thus able to share with other astronomers what in the case of visual observations can only be seen by those who have good enough atmospheric conditions to be able to detect them. In the case of visual observations other persons must place their faith on the judgment and accuracy of the observer, in the present case the photographs permit every reader to be his own observer and judge."

3. *Field Columbian Museum, Publication 95, Zoological Series*, vol. IV, parts I and II, pp. xx, 850, with sixty-eight plates and numerous text-figures.—These volumes are devoted to the "Land and Sea Mammals of Middle America and the West Indies," by Daniel Giraud Elliot. This admirable work follows the "Synopsis of the Mammals of North America and Adjacent Seas" by the same author and is intended to contain all the mammals of the remainder of the North American Continent, that is from the northern boundary of Mexico to the Province of Cauca, South America, including the coast islands, also part of Bahamas and West Indies. It is clearly presented and very fully illustrated.

4. *Statistical Methods with special reference to Biological Variation;* by C. B. Davenport. Second, revised edition, pp.

viii, 223. New York 1904 (John Wiley & Sons).—The first edition of this useful work was issued in 1899 (see this Journal, viii, 399). A second edition, somewhat enlarged, is now given to the public; the most important addition is that of the new statistical methods of Prof. Karl Pearson, his students and associates, with a summary of the results gained by them.

5. *Catalogus Mammalium, tam viventium quam fossilium;* a Doctore E.-L. TROUESSART. Quinquennale Supplementum, anno 1904. Berlin (R. Friedländer u. Sohn).—Fasciculus II, pp. 289–546, of the Supplement announced in the July number of this Journal (p. 94), has recently appeared. It is devoted to the Rodentia.

6. *Beitraege zur Chemischen Physiologie und Pathologie;* herausgegeben von FRANZ HOFMEISTER. Band V. Braunschweig, 1904 (Fr. Vieweg und Sohn).—The present volume of fifty pages is, like its predecessors, largely taken up with investigations on the proteids and their derivatives. A contribution by Dr. Kammann on the specific pollen toxin which gives rise to hay-fever, indicates that the poison belongs to the group of toxalbumins, is thermostable and not completely destroyed by proteolytic enzymes. These facts are of interest in connection with the recent attempts to induce immunity to hay-fever and to obtain a specific antitoxin. Various papers on blood-coagulation serve to render the explanation of this process more complex than ever before. Professor Röhmann has contributed an interesting paper on the skin glands (Bürzeldrüsen) of birds, throwing considerable light on the origin and composition of the secretion which they yield. The volume also contains several papers of physico-chemical interest, and a number of communications on enzymes, including important observations on amide-splitting ferments. L. B. M.

7. *Ostwald's Klassiker der exakten Wissenschaften.* Leipzig, 1904 (Wilhelm Engelmann).—The following parts of this series of scientific classics have recently appeared.

No. 143. Abhandlung über die Auflösung der numerischen Gleichungen (1835) von C. Sturm. Aus dem Französischen übersetzt und herausgegeben von Alfred Loewy. Pp. 66.

No. 144. Johannes Keplers Dioptrik, oder Schilderung der Folgen, die sich aus der unläugst gemachten Erfindung der Fernrohre für das Sehen und die sichtbaren Gegenstände ergeben (1611). Ubersetzt und herausgegeben von Ferdinand Plehn. Pp. 114.

No. 145. Über die Konstitution und die Metamorphosen der chemischen Verbindungen und über die chemische Natur des Kohlenstoffs: untersuchungen über aromatische Verbindungen von August Kekulé. Herausgegeben von A. Ladenburg. Pp. 89 with a plate.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XLI. — *Experiments on the Reception by Wires of Electric Waves;* by C. A. Chant.

The present paper contains an account of experiments on: (1) the nature of the disturbance about the receiving antenna in the system of wireless telegraphy devised by Braun and Siemens and Halske; (2) the radiation from the Braun, Slaby-Arco and simple Marconi forms of transmitters, observed by the method of resonance; (3) the effect on resonance of inserting a coherer in an open wire; (4) an exploration of wires receiving the radiation from a simple Marconi transmitter; and (5) a repetition of some of Slaby's fundamental experiments.

The paper may be considered as a continuation of a former one* dealing with the transmitting antenna in wireless telegraphy.

A number of investigations have been made on wires arranged as in wireless telegraphy for the reception of electric waves, but in almost every instance these have been restricted to observing a maximum effect at one place,—the base of the antenna,—and as detectors the spark gap, the hot-wire ammeter and the hot-wire thermometer have generally been used.

In my experiments the nature of the oscillatory disturbances was determined by means of the magnetic detector, used in the manner fully described in the former paper, and the exploration extended from one end of the wire to the other.

The wires, both for transmitting and for receiving the waves, were of bare copper, $0{\cdot}7^{mm}$ in diameter, stretched horizontally on the top of wooden posts, about $1{\cdot}5^{m}$ above the floor of the

* C. A. Chant, The Variation of Potential along the Transmitting Antenna in Wireless Telegraphy, this Journal (4), vol. xvii, p. 1, 1904. Phil. Mag., (6), vol. vii, p. 124, 1904.

large hall in which the experiments were made. The transmitting wire was about $1{\cdot}5^{m}$ from the wall, the receiving wire being farther out towards the middle of the room.

1. Exploration of the Receiving Antenna as used in the Braun, Siemens and Halske System of Wireless Telegraphy.

The apparatus used for these experiments was the experimental set supplied by the Gesellschaft für drahtlose Telegraphie, Berlin, Germany. The transmitter was described in the former paper, and the receiver was arranged as shown in fig. 1. The makers assert that the small set is of exactly the same pattern as their large commercial apparatus.

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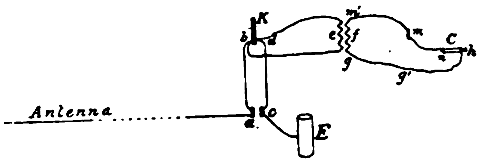

The antenna is connected to a, while to c is joined the earth-plate E, in this case a hollow metal cylinder 20^{cms} long and 8^{cms} in diameter. The receiving transformer is composed of two coils e, f, the former having 5 turns and a diameter of 8^{cms}, the latter, within the former, $5\frac{1}{2}$ turns and a diameter of $7{\cdot}6^{cms}$. At m is a very small condenser, inserted to avoid shunting the coherer C. The ends n, h, are joined to the polarized relay and a dry cell, not shown in the figure. The lengths of the various connections are as follows: ab, 20^{cms}; cd, 20^{cms}; bed, 126^{cms}; $gg'h$, 50^{cms}; $m'mn$, 30^{cms}; coherer, 8^{cms}; coil f, 131^{cms}; hence circuit $ghmfg$ is 219^{cms}.

The receiving antenna was parallel to, and directly opposite, the transmitting antenna, and 2 meters from it. In the first series of experiments the two antennæ were kept equal and both varied from 2 to 10 meters in length. Next, the transmitting antenna was kept 6 meters long and the receiving antenna varied from 2 to 6 meters; and lastly, the transmitting antenna was kept 4 meters long while the receiving one varied from 2 to 6 meters. The readings were taken in regular succession from one end of the wire to the other, usually at points 20^{cms} apart. The results of the examination are shown in Table I and the curves of figures 2 and 3. In the curves, ordinates represent magnetometer deflexions; abscissæ, lengths along the wire, measuring from the free end. Column 2 of the table, giving the position of the minima of the transmitting antenna, is taken from the former paper. It will be

TABLE I.

Transmitting antenna.		Length of receiving antenna and distance, in cms., of minima and maxima from its free end.								
Length.	Position of minima.	1000	900	800	700	600	500	400	300	200
1000	180, (320)	254, 620,* 940								
900	200, (790)		220, 500,* 830							
800	191, (745)			210, 440,* 636						
700	188, (637)				220, 430,* 600					
600	186, (375), (520)					210, 375,* 490	180?	340?	236	150
500	180						312			
400	187, (265)					None	340	300	210	150
300	218								210	
200	..									140

* Maxima.

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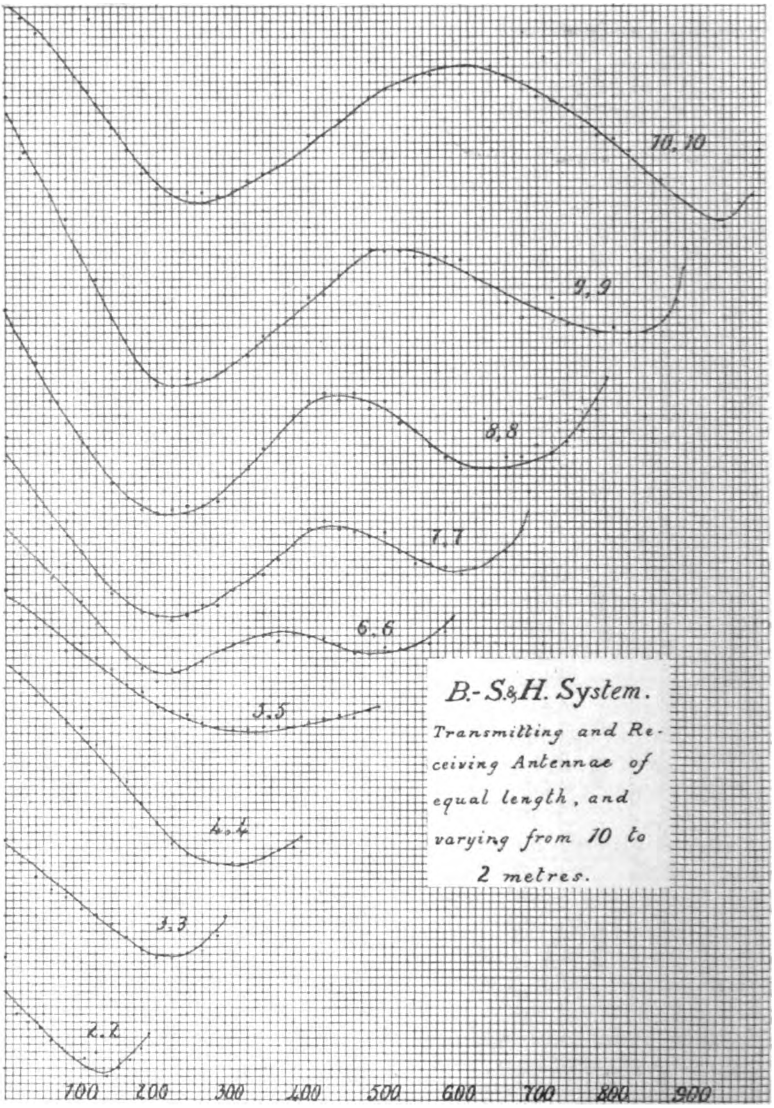

observed that in it there is a minimum at approximately 190^{cms} from the free end, and this length was interpreted in the former paper as a quarter-wave-length of the condenser circuit.

In the case of the receiving antenna the action appears more complicated. A study of the table and the curves indicates

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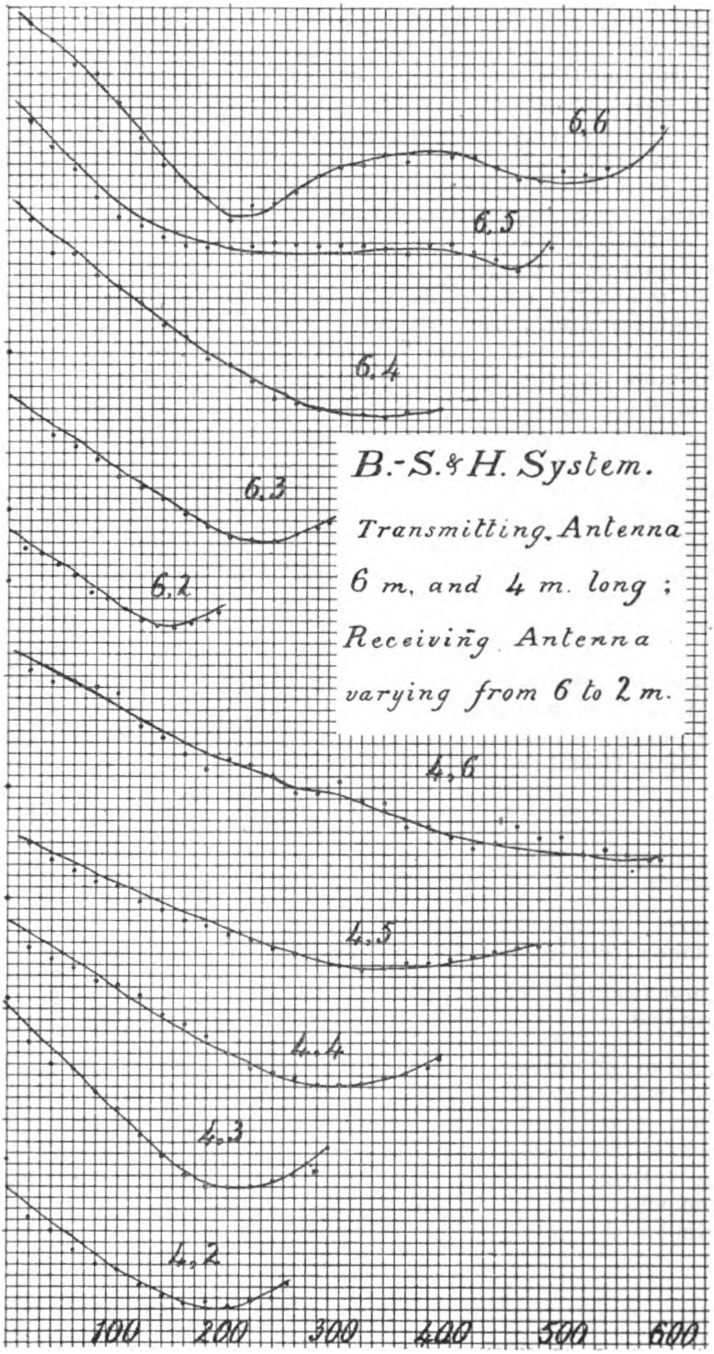
6,6
6,5
6,4
6,3
6,2
B.-S.&H. System.
Transmitting Antenna
6 m. and 4 m. long;
Receiving Antenna
varying from 6 to 2 m.
4,6
4,5
4,4
4,3
4,2
100
200
300
400
500
600

that there is one law for the wires 6 meters long and upwards, another for those shorter than 6 meters. With the former there is a minimum in the neighborhood of 220^{cms} from the free end. For the wire 1000^{cms} long it appears at 254^{cms} from the end, but this is not so sharply defined as the others, though five sets of readings were taken to obtain this curve while three were usually made for the others.

This appears to be a quarter-wave-length of an oscillation impressed on the wire, but not that shown on the transmitter. Again, if we assume that there is no displacement of the nodes upon reflexion from the free end, the maximum should be found at a distance twice as great from the free end. But such is not the case. There is a distortion of the oscillation, though for what reason it is not evident.

An attempt was made to see what length of the wire was equivalent to the receiver connections, i. e., to the portion from *a* to *E*, including *E*. In doing this the transmitting antenna was 4 meters long, arranged as usual. Opposite and parallel, at a distance of two meters, a wire 4 meters long was stretched, to act as the receiving antenna; and then, in place of the receiving apparatus, a long wire was attached at *a* and drawn vertically upward, to prevent, if possible, inductive action between this wire and the transmitting antenna. At first this wire was 9 meters long, that is, the entire length of the wire was 13 meters. The horizontal portion only was explored. Then the vertical wire was shortened to 8 meters and the horizontal portion again explored. This process was continued, shortening the vertical wire one meter at a step, until only the horizontal one remained. The results are shown in Table II and the curves of figure 4.

TABLE II.

Total length of wire in meters.	13	12	11	10	9	8	7	6	5	4
Distance, in cms., of minima from free end.	260	255	225	210	210	207	190, 304	304	253	202
Highest reading, i. e., at free end.	42	51	51	41	28	28	57	92	85	77

An examination of these shows that the wire 6 meters long, i. e., with 2 meters vertical, behaves like the 4-meter antenna when joined to the receiving apparatus, or that this apparatus behaves like 2 meters of wire. This method of substitution is not entirely free from objection, but I know of no better. Somewhat later it will appear from the same method that the cylinder *E* (fig. 1), is equivalent to about 80^{cms} of the same

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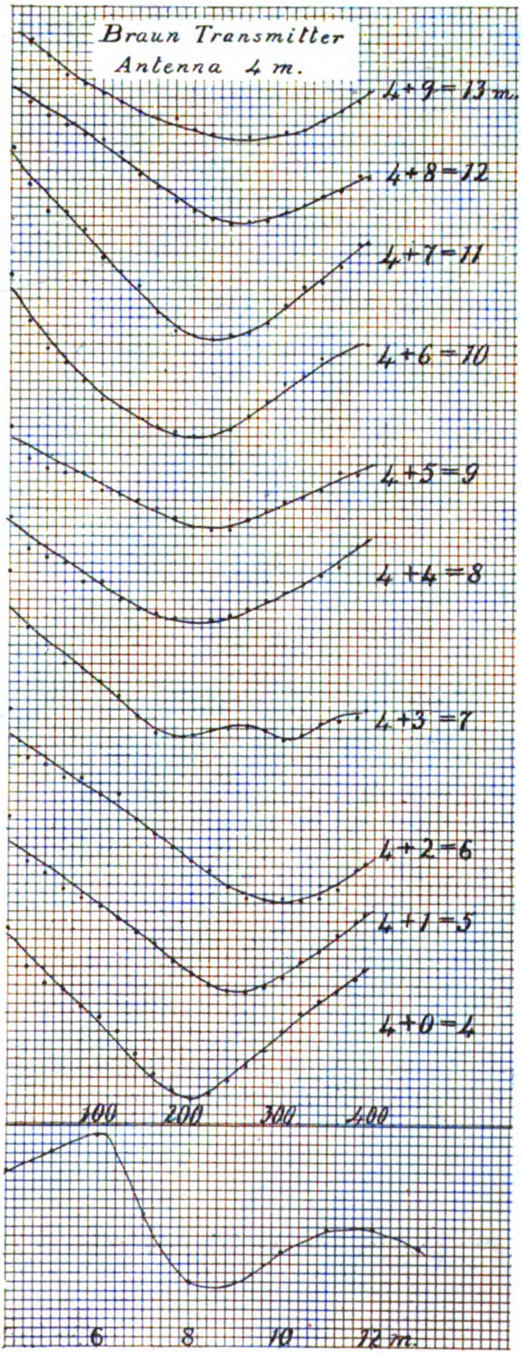
Braun Transmitter
Antenna 4 m.
4+9=13 m.
4+8=12
4+7=11
4+6=10
4+5=9
4+4=8
4+3=7
4+2=6
4+1=5
4+0=4
100
200
300
400
6
8
10
12 m.

wire. If we consider the connection from a to E to be equivalent to 200^{cms}, the above determination would make the condenser equal to 40^{cms} of the wire.

It will be observed in Table II that the minimum for wires of lengths 4, 5 and 6 meters is at the middle of the wire, or the wire is vibrating in its own fundamental mode, while with wires 8 to 11 meters long the minimum is about 210^{cms} from the free end, approximately as in Table I and almost certainly due to the same cause.

This would indicate that in the case of the longer wires the oscillation is forced on the wire, in the case of the shorter the oscillation is that natural to the wires themselves.

2. Examination, by the Method of Resonance, of the Radiation from the Braun, Slaby-Arco and Simple Marconi Transmitters.

In these experiments the transmitter was arranged as usual, and the receiving wire, as in the preceding experiments, was stretched parallel to the transmitting antenna. The action of the incident waves was measured by hanging the detector on the end of the wire. To begin with, the wire was of considerable length, and it was gradually shortened, 10 or 20^{cms} at a time, the effect on the detector hung on the end being observed for each length. As the length of the wire approached that for resonance with the transmitted waves the readings rose, but as the resonant length was passed they fell, until at last the wire was so short that the effect was hardly observable. From the curve obtained by plotting lengths of receiving wire as abscissæ and amount of demagnetization (measured by the magnetometer readings) as ordinates, the length of wire which gave maximum effect was easily determined. This method of determining resonant lengths is extremely simple and easy of application.

The Braun transmitter was the one used in the experiments just described, the antennæ being 3 and 4 meters long. The Slaby-Arco transmitter was that form of Braun's directly-connected system described in the former paper. In the simple Marconi radiator the transmitting antenna was joined immediately to the binding-post forming one terminal of the secondary of the induction coil; the other binding-post was joined directly to earth, while the spark-gap was between knobs 19^{mm} in diameter on the ends of rods passing through the binding-posts. The distance between these posts was 22^{cms}, and the earth-connection was 25^{cms} long, i. e., the distance to earth from the end of the wire attached for antenna was 47^{cms}.

The results obtained are shown in Table III and the curves of figures 5 and 6. The experimental arrangement seems simple and unequivocal, but the conclusions to be drawn are not all so.

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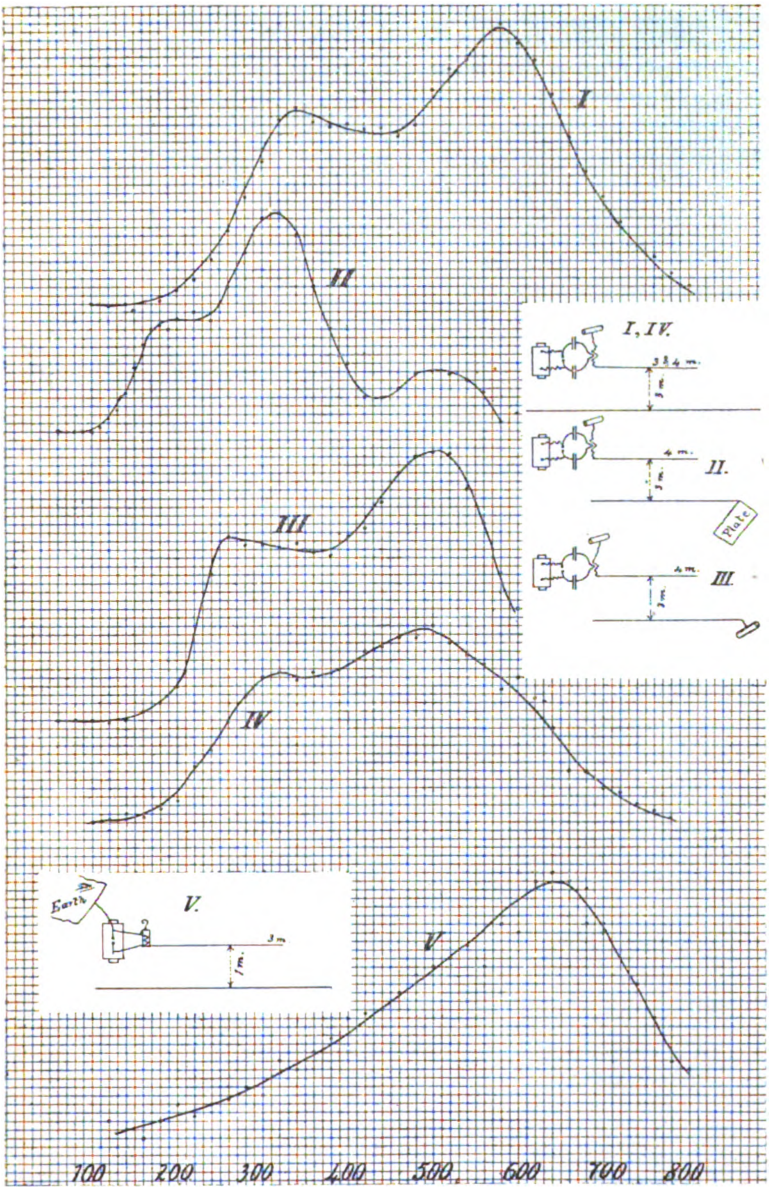

Curve I was obtained with a wire having both ends free, stretched at a distance of 3 meters from the transmitting antenna, which was 4 meters long. There are two definite

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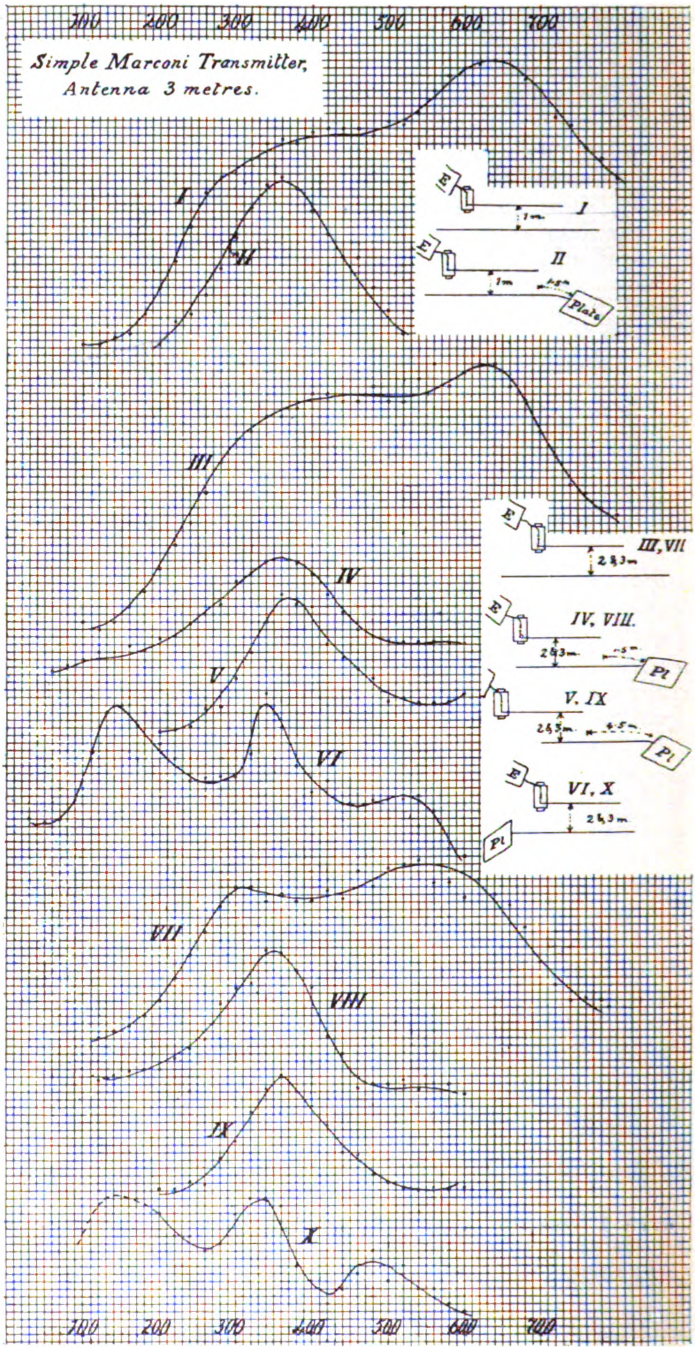
100 200 300 400 500 600 700
Simple Marconi Transmitter,
Antenna 3 metres.
I
II
III
IV
V
VI
VII
VIII
IX
X
E
1m
4.5m
Plate
III, VII
2 & 3m
IV, VIII.
Pl
V, IX
VI, X

maxima, showing that wires 335 and 580^{cms} long were in resonance with the radiator, i. e., the radiator emitted waves whose half-wave-lengths were 335 and 580^{cms}, respectively. The latter appears to be the chief one, which fact is indicated in the table by the change in type. The bottom curve in fig. 4 is plotted from the data contained in the lowest line of Table II, ordinates denoting the readings at the end of the wire, abscissæ

TABLE III.

Method of Resonance.

Description of transmitter.	Distance of receiver from transmitter.	Length for maximum reading.	Arrangement of receiving wire.
Braun, 3^m antenna	3 meters	318, *496*, 595	Free wire
" 4 "	"	335, 580 (850,* 1160)	" "
" " "	"	190, *313*, 502	Plate on outer end
" " "	"	*286*, 518	Double plate on outer end
" " "	"	187, *300*, 520	Good earth on outer end
" " "	"	206, *280*, 513	Good earth on inner end
" " "	"	270, *500*	Cylinder on outer end
Simple Marconi, 3^m antenna	1 meter	420, *650*	Free wire
" " "	"	*355*	Plate on outer end
" " "	"	415, *640*	Braun coh'r in free wire
" " "	"	410, *645*	Iron turnings coh'r in free wire
" " "	"	400, *650*	Silver powder coh'r in free wire
" " "	2 meters	400, *620*	Free wire
" " "	"	*360*	Plate at outer end
" " "	"	*365*	" " " "
" " "	"	153, *342*, 533	" " inner "
" " "	3 "	310, 550	Free wire
" " "	"	*348*	Plate at outer end
" " "	"	*360*	" " " "
" " "	"	150?, *336*, 480	" " inner "
Slaby-Arco, 3^m antenna.	1 meter	*638*	Free wire

* Minimum. These two readings are from the bottom curve in fig. 4. The value 580 is found there also.

the length of the wire. The maxima are at 580^{cms} (the value just given), and 1160^{cms} ($=580\times2$), and a minimum at 850^{cms}, half way between.

Next, a large plate of metal, 90 by 180^{cms}, standing in a vertical plane perpendicular to the wire, was securely joined to one end of the wire, which was then examined as before. Here with a capacity so large one would almost expect resonance to take place with wires one-half the previous lengths. But such was not the case, the chief resonance being with a length of 313^{cms}, and less pronounced effects with lengths 190 and 502^{cms} (Curve II). With a plate twice as large, however, the chief resonance was with a wire 286^{cms} long. Next, a good earth was obtained by soldering together metal sheets (total length 6·6 meters, width 80^{cms}) and securely binding one end of the strip so formed to a heating radiator. The maxima are given in the table. When the earth was on the outer end of the wire the chief maximum was given with a length of 300^{cms}, when on the inner end a maximum was given with 280^{cms}. The mean of these two values, 290^{cms}, is exactly half that with the free wire.* This is evidence that on reflection at the free end of a wire there is no loss of phase.

On attaching the small cylindrical capacity supplied with the instrument in place of the large plate, the curve III was obtained, best resonance being given with a wire 500^{cms} long, a smaller effect with 270^{cms}. Curve IV was obtained with the same disposition as for curve I, but with antenna 3 meters long.

It is seen that the cylinder capacity reduces the length of wire from 580 to 500^{cms}, and thus it may be considered, in an oscillating system, as approximately equivalent to 80^{cms} of the wire.

Curve V shows the resonance effect with the Slaby oscillator of antenna 3 meters. It shows resonance for a single half-wave-length of 638^{cms}.

In figure 6 are exhibited resonance effects obtained with the simple Marconi radiator with antenna 3 meters long, the receiving wire being at different distances and arranged in different ways. Curves I and II were taken with the receiving wire 1 meter from the transmitting antenna, III to VI with the distance 2 meters, and VII to X with it 3 meters. Curves I, III, VI refer to a wire free at both ends; II, IV, V, VII, IX with a large plate at the outer end; and VI and X with the plate at the inner end. In every case the plate stood in a plane perpendicular to the wire.

* In the former paper the experiments led to the conclusion that a large capacity (e. g., the earth) joined to a vibrating system acts like a plane mirror in optics, a result first predicted by J. von Geitler, Wied. Ann., lv, p. 313, 1895.

For the wire free at both ends there are two resonant lengths, the resonance not being very sharp, just as we should expect it to be with a radiator much damped. With the plate on the outer end, however, there is only one maximum, which is very clearly marked; while with the plate on the inner end there are three resonant lengths, the chief one being somewhat shorter than with the plate in the former position. From theoretical considerations Wien* concluded that with both the inductively- and the directly-connected radiators there should be present two distinct sets of waves of different periods and damping coefficients. With the Braun apparatus this is clearly evident, but there is no trace of a second maximum with the Slaby radiator. On the other hand, the simple Marconi radiator gives two resonant lengths when the wire is free at both ends, only one, however, with the plate on the outer end, while three are shown when the plate is on the inner end. The reason for this is not easy to see.

Again, the chief resonant length with the plate on the inner end is shorter than with the plate on the outer end. The only reason I can suggest for this is that the presence of the large metal plate alters the frequency of the radiator to some extent, even though it be 2 or 3 meters away. Slaby† found that wires stretched one meter above a zinc-covered floor gave a wave-length ten per cent smaller than when the floor was entirely of wood. He traced this to a variation of the self-induction of the radiator, not of its capacity.

3. The Effect on Resonance of Inserting a Coherer in an Open Circuit.

To test for this effect the coherer was inserted in the middle of the straight wire arranged as in I, II, VII, fig. 6, and this then gradually shortened for resonance as before. The simple Marconi radiator with antenna of 3 meters was used and the receiving wire was 1 meter away.

Three coherers were experimented with. The first was the one supplied with the Braun apparatus. The second was of iron turnings in a tube 20^{cms} long and having an internal diameter of 8^{mm}. The third had silver plugs 3^{mm} in diameter, 1^{mm} apart, with about one-fifth of the space between filled with fine powder, mostly of silver. In each case a decohering tapper was arranged on an independent circuit and was kept in continuous action.

* M. Wien, Wied. Ann., lxi, p. 151, 1897; Ann. der Physik, viii, p. 686, 1902; see also G. Seibt. Phys. Zeitschrift, iv, p. 485; Graf Arco, Elektrotechnische Zeitschrift, 1903, p. 1; A. H. Taylor, Physical Review, xviii, p. 230, 1904.

† A. Slaby, Der Multiplikationsstab, ein Wellenmesser fur die Funkentelegraphie, § 7, Elektrotechnische Zeitschrift, No. 50, 1903.

The resonant lengths are given in table 3, but the curves, being quite similar to I, fig. 6, are not shown.

The conclusion was that the coherer did not alter the resonance, that it behaved like its length of good conductor. This agrees with Kiebitz's* results.

4. Exploration of Wires receiving Radiation from the Simple Marconi Transmitter.

In these experiments the antenna was 3 meters long, with the receiving wire (unless otherwise stated) 1 meter distant. The general arrangements are shown in fig. 7.

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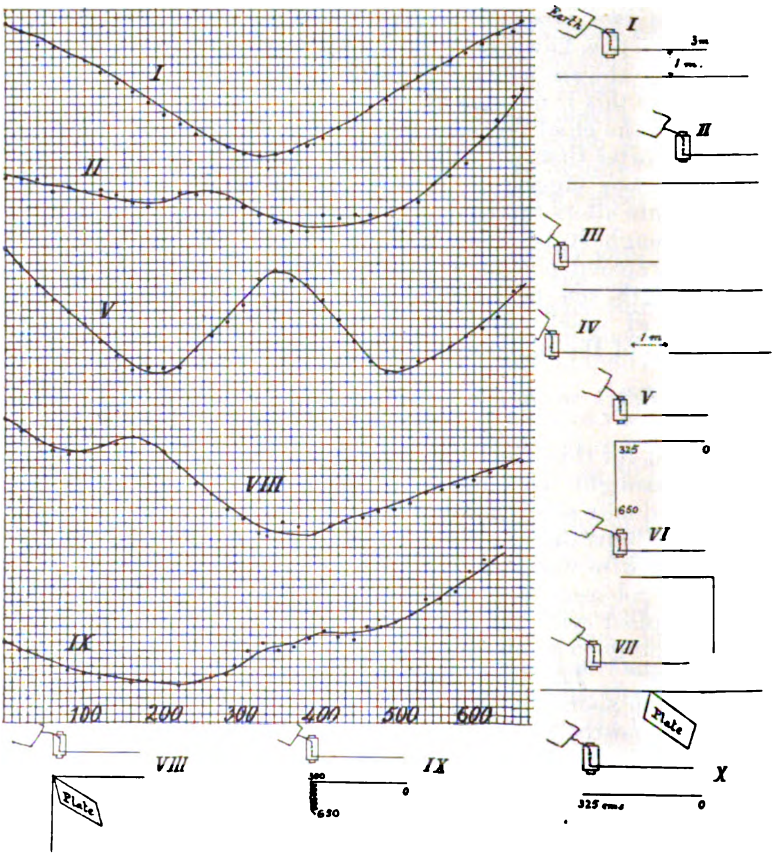

The receiving wire in every case but the last was 650$^{\text{cms}}$ long, which length was found in experiments just described (see curve I, fig. 6) to be resonant with the transmitter.

* F. Kiebitz, Ann. der Physik, v, p. 872, 1901; vi, p. 741, 1901.

The exploration showed that with the wire arranged as in I. fig 7, there was present only the fundamental, perfectly formed (see curve I, fig. 7). When the wire was moved along to the position shown in II, the vibration was roughly in the fundamental mode, but very poorly formed, the highest reading being but two-fifths of that in I (see curve II). When, however, the receiving wire was moved along to the position shown in III, the fundamental was well-formed and one-fourth more powerful than in I. This shows that the position of the receiving wire is of importance, the greatest effect being given when the middle of the wire is opposite the end of the antenna. Abraham* has remarked that on account of the transversality of the vibrations, there should be no radiation in the direction of the axis of the antenna. Arrangement IV was to test this conclusion; it was found that the receiving wire responded in a decided manner, a well-formed fundamental being present one-half as powerful as in I. The arrangement V gave the curve shown, the minima being at 180 and 486, the maximum at 352, corresponding roughly to the first harmonic of the wire. The greatest reading was about one-fourth that in I. With a wire bent in the same way but placed as in VI, the fundamental oscillation proper to the wire and as powerful as in I was exhibited. This is a rather striking result. The arrangement VII, with the large metal plate at the center, was indistinguishable from I. That for VIII (the same as V with the plate added at the bend in the wire) gave the fundamental somewhat distorted shown in curve VIII. In IX the coils had a diameter of about $5{\cdot}5^{\mathrm{cms}}$, and were 2^{cms} apart. In this case the fundamental was very roughly formed (see curve IX), with the reading at the end of the coil twice as great as at the end of the straight portion. This shows the "multiplication" effect utilized so capably by Slaby and von Arco, though it was not nearly so great as it would have been had the length of the coil been properly adjusted for resonance. In X the wire was half-length, i. e., 325^{cms}, and the fundamental was well-formed, half as powerful as in I.

5. *Repetition of some of Slaby's Fundamental Experiments.*

The methods here used for determining resonant lengths and for exploring the wires seemed well suited for repeating some of Slaby's† fundamental experiments, and my results in some cases were somewhat different from those published.

Each half of the oscillator consisted of a brass rod $3{\cdot}4^{\mathrm{mm}}$ in

* M. Abraham, Ann. der Physik, ii, p. 32, 1900.

† A. Slaby, The Scientific Basis of Spark Telegraphy, Elektrotechnische Zeitschrift, No. 9, 1902; Lond. Electrician, vol. xlix. p. 6, 1902. Also, Der Multiplikationsstab, etc., Elektrotechnische Zeitschrift, No. 50, 1903.

diameter, ending in a knob 9·5mm in diameter, the length over all being 1 meter. The spark-length was 2·8mm in air, and the knobs were kept polished for good effects.

First, the length of wire required for resonance with the oscillator was found as explained in section 2. The experimental

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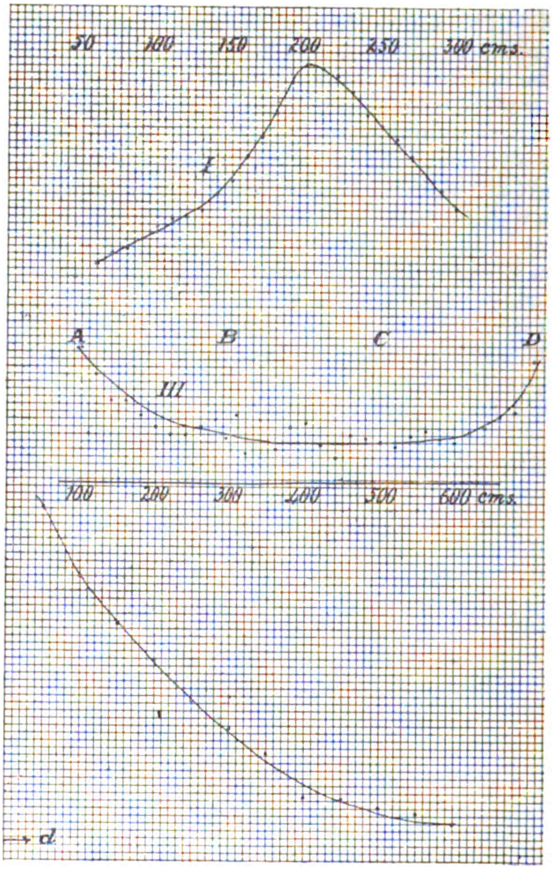

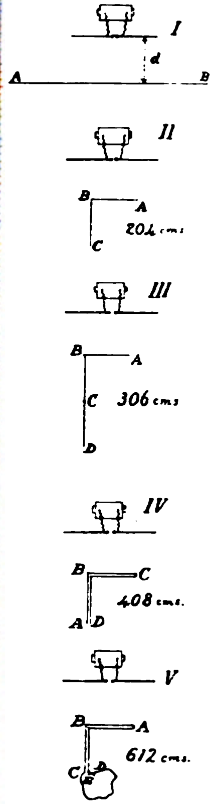

disposition is shown in diagram I of figure 8, distance *d* being 1 meter, and curve I shows the result. Resonance was well-marked, attaining a maximum with a length 204cms. This is evidently the half-wave-length of the oscillator. Then the wire AB was made in succession 204cms and 102cms long, and at a distance, *d*, of 1 meter, was explored when exposed to the action of the oscillator. In each case there was a well-marked fundamental.

With the wires 204^{cms} long, bent at the middle and placed as in II, the oscillation was the fundamental proper to the wire with node at B. When a wire 306^{cms} long was bent and placed as in III, the effect was weak and the vibration poorly formed, as shown in the corresponding curve. There is a loop of potential at each free end, and no other pronounced feature. With 408^{cms} of wire doubled and bent as in IV, the vibration was perfectly formed with nodes at B,D, loops at A,C,E.

Next, a wire 612^{cms} long, the straight portions being the same as in IV, and the bent portion CD being 204^{cms} long, was examined, first with a Braun coherer between the ends D,E, and secondly with the ends D,E joined directly. The effect on this closed circuit was small, with no trace of nodes or loops to be found.

Then a wire 280^{cms} long, arranged as in I, was explored. Here the wire was much out of resonance. The vibration was the fundamental proper to the wire and very well formed.

Lastly, the relation between the magnitude of the effect and the distance of the resonating wire from the oscillator was determined. For this the wire was 204^{cms} long, and the distance d was varied from 50 to 600^{cms}. In the accompanying curve abscissæ give the distance d, the ordinates the corresponding demagnetization of the detector hung on the end of the wire. It will be seen that the curve is hyperbolic in form, and the effect, therefore, varies inversely as the distance.

University of Toronto, Toronto, Canada.

Art. XLII.—*Spectra of Gases at High Temperatures;* by John Trowbridge.

[Presented at the International Electrical Congress of St. Louis, 1904.]

The new theories in regard to the complexity of the atom, together with a multiplicity of ionization phenomena, make the results of spectrum analysis obtained by the discharges of electricity in glass or quartz tubes difficult of interpretation. To use ordinary language, "so many things can happen," such as dissociation; combination with the gases set free from the walls of the containing tubes; masking of the spectrum of one gas by that of another, reversals of spectrum lines and so on.

These complicated conditions which accompany our study of gaseous spectra make it almost impossible to conclude from laboratory experiments that we have imitated the phenomena presented by the distant stars.

For several years I have been endeavoring to obtain new series of hydrogen lines which might presumably manifest themselves at very high temperatures. In the progress of this work I have obtained a number of interesting facts which I shall dwell upon in a brief manner in this paper; but I have failed to find a new series of hydrogen lines, possibly from the reason that the reactions both in glass and quartz vessels mask the series. It seems impossible to experiment at a higher temperature than I have obtained, certainly if one employs such vessels as I have mentioned.

My investigations have been conducted with a storage battery of 20,000 cells, which were used to charge large condensers. The advantages in using a storage battery for experiments in spectrum analysis are well recognized. These advantages are especially seen in the employment of condenser discharges. When the condensers are charged through a large liquid resistance they charge to the same potential each time, and then discharge without the intervention of a discharger, through the Geissler tube. The number of discharges can be closely regulated by the amount of liquid resistance which connects the poles of the condensers to the battery. The regularity of such discharges through the Geissler tubes is remarkable. In popular language one can call the arrangement an electric clock, for the discharges follow each other at regular intervals. In this way one avoids the spark at a discharger and is sure of always obtaining the same difference of potential at the ends of the Geissler tube.

The highest temperature to which one can submit a gas is presumably that of the electric discharge from a condenser; opinions differ in regard to the degree of heat which one can

obtain by such a discharge. The limit I have reached is the volatilization of silica; perhaps 1800 degrees. At this temperature the spectrum shown by all gases in narrow capillary tubes consists of a continuous spectrum crossed by broad bands due to silica or to an oxide of silica; the gaseous spectra are completely masked. This masking seems to be due to the greater conductibility of the volatilization products from the walls of the tubes and from the metallic terminals. It seems to me that this variation in conductibility is sufficient to account for the phenomena of masking without recourse to a theory of electrons which provides for suitable damping of electrical oscillations. The electron theory may be an ultimate explanation, however, of electrical conduction.

When terminals of different metals are employed in capillary tubes of glass or quartz, and are separated four or five millimeters, complicated phenomena result from powerful condenser discharges through the rarified gases contained in these tubes.

All specimens of glass which I have tried, soft German glass, lead glass, Borsilicon glass, or Jena glass, give broad bands due to silica; lead glass gives, in addition, lead lines. Jena glass gives a very strong line of boron at wave length 3451·49. These lines and bands are obscured by a continuous spectrum.

The narrow capillaries with metallic terminals, which I have used, may be called electric furnaces in which there is no permanent product or permanent decomposition; moreover, the spectra which we observe do not reveal all that the capillaries contain. Hydrogen may be present; but it is concealed. Oxygen shows its presence only by probable oxides; the constituents of rarified air are undoubtedly always there. The conditions which prevail in the case of discharges in such narrow capillaries seem to be analogous to those in the case of discharges under liquids. In this latter case we also have reversals of metallic lines; and, moreover, certain characteristic lines of metals are wanting—see "Spectra from the Wehnelt Interrupter," Harry W. Morse. (Proc. American Academy of Sciences, May, 1904.)

These results make one doubtful in regard to the entire subject of spark spectra which are observed between metallic terminals in ordinary air; and we are forced to ask, what influence does the environment have upon the character of these spectra—to what must we attribute the presence of oxygen? And even if we take spark spectra between metallic terminals in an atmosphere of hydrogen or nitrogen we are not sure that the results are not modified by the gases which are occluded in the metallic terminals.

Are we sure that, even in electrodeless tubes, helium is a

product of disintegration of radium; a transmutation, so to speak; and is not a result of the electrical stimulus in the environment of glass or quartz a stimulus which may bring to light the helium which has refused to manifest itself by chemical analysis?

In general it may be said that the greater the conductibility of the volatilization, products either from the walls of the tubes or from the metallic terminals determine the occurrence of the spectral lines or bands. The spectrum, for instance, of silica completely masks the spectrum of the iron terminals when the latter are placed not more than five millimeters apart. When the terminals are of different metals the spectrum of the more volatilizable metal predominates: or more strictly, the spectrum of the better conducting vapor.

Another striking fact brought to light by such discharges in capillaries is the reversal of many of the spectral lines on broad bands. The broadening of the lines of the metals is generally toward the red end of the spectrum. The quantity of the discharge appears to be the important factor in determining the character of the spectra; electromotive force, *per se*, does not give new lines which can be detected by photography. The effect of high electromotive force begins to be evident at high exhaustions and then only in producing cathode and X-rays.

This latter fact can be well shown by a Tesla coil actuated by a Cooper-Hewitt mercury interrupter such as was employed by Dr. G. W. Pierce (Proc. Am. Acad., 1904). With a suitable step-up transformer, in connection with such an interrupter, I have studied the spectrum of hydrogen, and have not obtained a spectrum which differed from the one obtained by the same amount of energy with a lower voltage. The high voltage ranged from 100,000 volts to 3,000,000.

The broadening of metallic lines seems to indicate an oxidization. One can conceive of a loading of the metallic molecule by various degrees of oxidization which leads to a broadening towards the red end of the spectrum, or in other words to longer wave lengths, and an unloading due to dissociation which leaves the molecule free to emit shorter wave lengths. That an oxidization results from a discharge of electricity in glass or quartz tubes filled even with apparently dry hydrogen seems to me to be evident from my experiments. The unavoidable presence of water-vapor in glass, and I may add, in quartz tubes, lends color to this oxidization theory; this vapor is dissociated by the electric current, the oxygen, set free, combines with the molecules of the metals, or with the molecules of silica and its metallic impurities.

The following experiment illustrates this oxidization:

A Geissler tube, fig. 1, with an internal diameter of one inch, was provided with an inner capillary, one end of which was blown to the walls of the larger tube; the other end was free inside this larger tube. An electric discharge passed between two ring electrodes A and B, which were placed in the larger tube. The discharge, therefore, started, so to speak, in the larger tube, passed through the narrow channel of the capillary and emerged to the cathode. The tube was filled with pure hydrogen which was dried by phosphoric pentoxide. Under the effect of powerful condenser discharges, the four-line spectrum was much enfeebled in the capillary; the red color, characteristic of condenser discharges in hydrogen, gave place to a brilliant white light, and when the capillary was viewed end on, a continuous spectrum was seen. When, however, the discharge issued from the capillary a brilliant red aureole was seen around the end of the capillary. This aureole gave a much enhanced four-line spectrum. The temperature inside the capillary was sufficient to volatilize the walls of the capillary, and, therefore, was competent to decompose the water-vapor into oxygen and hydrogen. Just outside the end of the capillary, the temperature fell to the point of recombination of these gases to water-vapor.

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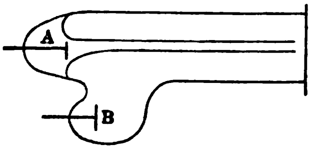

In another experiment the Geissler tube G, fig. 2, was placed between two manometer gauges, and was exhausted to such a degree that the electric discharge failed to pass. One end of the Geissler tube, that nearest to the pump, was shut off by

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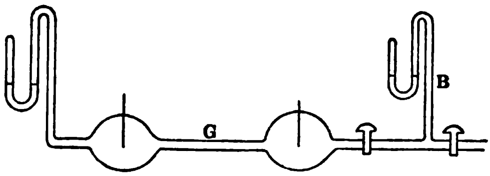

means of a stopcock B; and dry oxygen was admitted to the pump until the manometer gauge connected with the pump indicated two centimeters pressure. The stopcock was then opened so as to admit the gas to the Geissler tube. The corresponding manometer gauge at the opposite end of the Geissler failed to register the requisite equalization of pressure, there having arisen an oxidization of the mercury meniscus by means of which the capillary constant between it and the glass

had been changed. This holding of the mercury meniscus was large and had to be overcome by vigorous tapping of the tube. An analogous effect was obtained when the Geissler tube was filled with rarified air, and also when it was filled with nitrogen. When, however, it was filled with dry hydrogen, the holding effect was comparatively inappreciable. The oxygen produced by the dissociative effect of the electric discharge combined with the hydrogen and no longer oxidized the surface of the mercury. In this connection it may be observed that the mercury meniscus in the Lippman electrometer is affected principally when it is made the positive pole, and, therefore, oxygen is liberated.

Perhaps the most striking experiment in this connection can be made with the steady current from a large storage battery. When Geissler tubes, preferably of half a centimeter internal diameter, are provided with copper terminals, and are filled with dry hydrogen at pressures of one millimeter to one-tenth of a millimeter, a steady diminution in the pressure of the gas results from the application of the discharge; the light of the spectrum grows dimmer and dimmer, then the cathode rays appear, finally the X-rays, and then no discharge can be forced through the tube until a much higher electromotive force is employed, or heat is applied to the tube. This heat evidently drives off water-vapor from the walls of the tube together with air; a fresh application of the steady current again diminishes the pressure in the tube to an apparent vacuum. Thus one can exhaust, so to speak, a Geissler tube by employing a steady current of electricity to dissociate the ever present water-vapor. With copper electrodes, the oxidization produced by this dissociation is more evident than with the other metals; although I have observed it with magnesium terminals, with iron terminals and with other metals.

These experiments lead me to believe that, just as in chemical reactions, a certain amount of water-vapor or humidity is essential to conduction in gases whether brought about by what is called chemical affinity or electrolytic action.

I have dwelt upon the broadening of the lines of metals in capillary tubes. This phenomenon is also observed with hydrogen lines, and was first noticed by Liveing and Dewar, Chem. News, xlvii, p. 122, 1883. These authors attributed the broadening to compression of the gas in the narrow capillary under the effect of a powerful condenser discharge. Their method of experiment was as follows: The tube was exhausted only to perhaps five or six centimeters pressure, so that a white discharge of a spark nature passed through the capillary and then spread out to electrodes placed in the large ends of the tube. When the tube was viewed end-on, a continuous spec-

trum was seen in the capillary; moreover, this continuous spectrum was crossed by a dark line which resulted from the absorption of heat in the colder layers of gas in the larger portions of the tube.

The broadening of the spectra of the vapors of metals which I have observed in capillary tubes has thus its analogy in the case of gaseous spectra.

Having obtained reversals of the spectra of metallic vapors under new conditions, I was naturally interested in the experiment of Liveing and Dewar, especially since a controversy had arisen between M. Cantor and E. Pringsheim in regard to the possibility of the reversal of gaseous lines in Geissler tubes. M. Cantor* concluded from his experiments that such reversals do not occur in the phenomena of luminescence, such as one obtains by the discharges of electricity in Geissler tubes. Pringsheim objected to these conclusions on the ground that Cantor did not observe a sufficiently narrow portion of the spectrum of the gas and did not use sufficient dispersion. Pringsheim† quotes the results of Liveing and Dewar in support of his position.

In repeating Liveing and Dewar's experiment, it occurred to me that objection might be brought against it on the ground that it was a spark discharge and not a clearly marked glow or luminiscent discharge such as Cantor evidently had in mind. I, therefore, placed a second spark gap (fig. 3, S) just outside the inner capillary of the large Geissler tube provided with an

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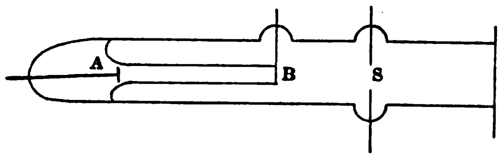

inner capillary, as I have previously described in speaking of the temperature inside a capillary and in the space just outside. The discharge passed first through the capillary and then by means of an outside connection through the second spark gap; thus the light from the capillary passed through the light from the second spark gap. In both cases the light was a glow or luminescence and not a white spark discharge, the pressure in the tube being from one to two centimeters.

A Rowland grating was employed and an eye-piece was fixed on the C line of hydrogen. The second spark gap gave a fine bright line of the apparent length of the slit, the capil-

* Ann. der Phys., 3, 462, 1900.
† Ann. der Phys., 5, 1900.

lary a continuous spectrum, and where the fine bright line crossed this continuous spectrum, it was reversed.

Kirchhoff's law of radiation thus applies to the radiation in Geissler tubes, and Pringsheim's contention is justified. If the solar corona is an electrical phenomenon of the nature of luminescence, it can exhibit either bright lines or dark lines according as it is hotter or colder than the background.

In this study of the upper limit of temperature which one can reach by electric discharges through rarified gases, we perceive that spectrum analysis is one of the most difficult analyses which modern science has revealed. There are a few broad facts such as Doppler's principle and the reversal of spectral lines according to Kirchhoff's law; on the other hand, there is ionization, dissociation, adsorption and absorption, all modified by the glass or quartz vessels which must be employed.

M. Cantor calls attention to the fact that Hittorf failed also to observe reversals of spectral lines in the case of electric discharges in Geissler tubes. Hittorf speaks of a first series of hydrogen lines which are seen with feeble discharges. This feeble spectrum with its bands seems to be a peculiarly luminescent effect in which any translatory or colliding effect of the molecules is a minimum. The new theories in regard to the composite nature of the atom seem to demand an extension of our views in regard to the nature of the light emitted by atoms and their aggregates under the stimulus of an electric discharge. The phosphoreseent and fluorescent light of a gas under this stimulus may arise from the mechanism of the atom and therefore may not give sensible heat. The combination of atoms into molecules, and their dissociation and formation of new combinations, may give the spectra we usually observe under the effect of fairly strong electric discharges, and provide the sensible heat which can be measured by the bolometer or the thermal junction.

Spectrum analysis of the future thus becomes more and more difficult of application, and one of its most important fields is in the study of phosphorescent and fluorescent light emitted by gases. We seem to be on the point of regarding the light and heat of the sun more from the electrical standpoint. And the study of discharges of electricity in rarified gases assumes a great importance.

ART. XLIII.—*Two New River Reptiles from the Titanothere Beds;* by F. B. LOOMIS.

ALTHOUGH the Titanothere beds of the White River formation are usually regarded as of flood plain origin, the known distinctively river animals are very few. Such forms as Elotherium and Cænopus lived along the river banks; but of those dwelling in the water itself, none has been described, although occasionally a reference is made to fragments of Trionyx. The Amherst College Expedition of 1903 found two well-preserved river forms, which, together with a remarkable case of redeposition of Cretaceous fossils in the White River beds, make the basis of this paper.

Several times in the Oligocene "Bad Lands" along the Cheyenne River fragments of crocodilian dermal scutes were found; and, finally, in the Finney Breaks near Fulsom Post Office, S. D., a specimen came to light, consisting of 10 vertebræ, 25 dermal scutes, the femur, tibia, astragulus and a number of fragments. Then, in the museum of the South Dakota School of Mines, Prof. O'Hara showed me a crocodilian snout, found in the Titanothere beds in Indian Draw, distant some six miles from the first specimen. This imperfect skull is used as the type of the new species; and the skeletal parts, inasmuch as they are of dimensions appropriate to the skull, are referred to the same species, of which the following is the description.

Crocodilus prenasalis, nov. spec. Figs. 1–9; 1–6, $\times\frac{1}{2}$, 7–9, $\times\frac{1}{4}$.

The front end of the cranium with nine tooth alveoli on either side is preserved, together with the anterior part of the lower jaw, still in position. The snout is broad and short, indicating a wide head. The undivided nasal opening is very far forward, and differs from that of other crocodiles in the lack of a distinct anterior border, this portion of the nasal cavity having a smooth, rimless boundary on the præmaxilla. The nostril opening would seem, therefore, to have been directed to the front rather than upward on top of the snout. (This lack of a rim gives the snout a distinctly mammalian appearance.) The boundaries of the frontals are not distinct, but if what appears to be the suture is correct, they are unusually wide. Their upper surface is covered with good-sized pits. On the left side, just where the snout is broken off, is a constriction on the maxilla to receive a tooth of the lower jaw. This comes just behind the ninth superior tooth, but just which tooth of the lower jaw would fit into it cannot be determined, as the two jaws are closely interlocked. The two halves of the lower jaw are completely fused at the symphysis.

The teeth preserved (the eighth and fourth superiors on the left side) are conical, slender and slightly recurved.

The vertebræ are all deeply procœlous. Those of the lumbar region have heads (posterior), which are short, wider than high and rectangular in outline. Those of the dorsal region, however, are smaller and have prominent conical, rounded heads.

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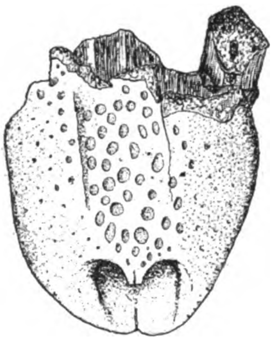

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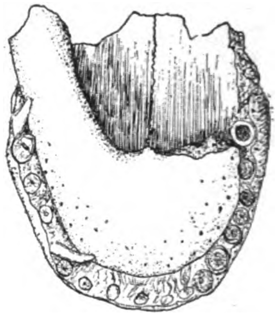

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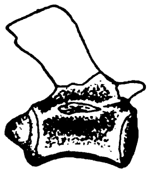

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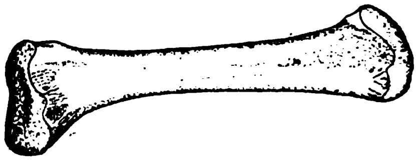

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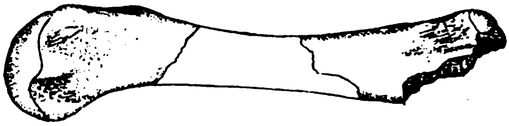

The dermal scutes are of many shapes, mostly quadrilateral. Some have sutures on both lateral margins and seem to have been in rows up and down the back. I should judge there were four rows. Some have the suture along one side only, and must have belonged to the outside rows. And lastly, a few seem to have lain free in the flesh, having no trace of a contact. Types of each sort are figured (figs. 7–9, $\times\frac{1}{2}$). All are deeply and profusely pitted. Those which were in the rows have a more or less marked ridge running lengthwise.

The femur has a wide flattened head, the articulation extending around the whole end as in the modern forms. The tibia is very like that of a living *C. palustris*, as is also the astragulus, which, however, has a shorter heel.

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8

9

For measurements see the figures, which are all to scale.

Chrysemys inornata, nov. spec. Figs. 10, 11. $\times \frac{2}{5}$.

The genus Chrysemys, to which Hay* ascribes many of the Eocene species described as Emys, has not been heretofore found in the Oligocene, although to be expected in river deposits. A good many small undeterminable fragments were picked up through the summer; and finally, while excavating a titanotherium skeleton at the head of Bear Creek in Spring Draw Basin—ten miles east of Creston Post Office,—directly under the skull, as though crushed by the fall of that animal, was discovered a complete carapace and plastron of *C. inornata*.

The carapace is broadly oval and but moderately convex. The anterior margin has a shallow median notch: the posterior a distinct median notch, and on either side three diminishing scallops, one on each marginal plate. The nuchal plate is much wider than long; so that its lateral corners underlie the first costal scute on either side. The antero-lateral borders of vertebral plates numbers 1 to 6 are much shorter than the postero-lateral borders. The anterior sulcus of dorsal scute number 5 crosses the anterior end of neural plate No. 9. In general appearance this species closely resembles *Emys lativertebralis* Cope† from the Wasatch: but on *C. inornata* the posterior margin is scalloped (resembling *C. scripta* in this respect). Then in *E. lativertebralis* the nuchal plate does not extend under the first costal scute. Lastly, the tenth neural plate of *C. inornata* is longer than that of *E. lativertebralis*, while the eighth is shorter.

The plastron is about two-thirds the width of the carapace, the meso-sternal plate being anterior to the pectero-humeral suture. This plate is as wide as long and broadly rounded.

*Bull. U. S. Geol. Surv., No. 179, p. 447. This Journal (4), xviii, 267, 1904. † Geog. Surv. West of 100 Meridian, vol. iv, p. 58.

The posterior lobes of the plastron end in broad points, due to the inner margin of the anal plates being deeply excavated.

The shell throughout is thin, the sutures being strongly marked.

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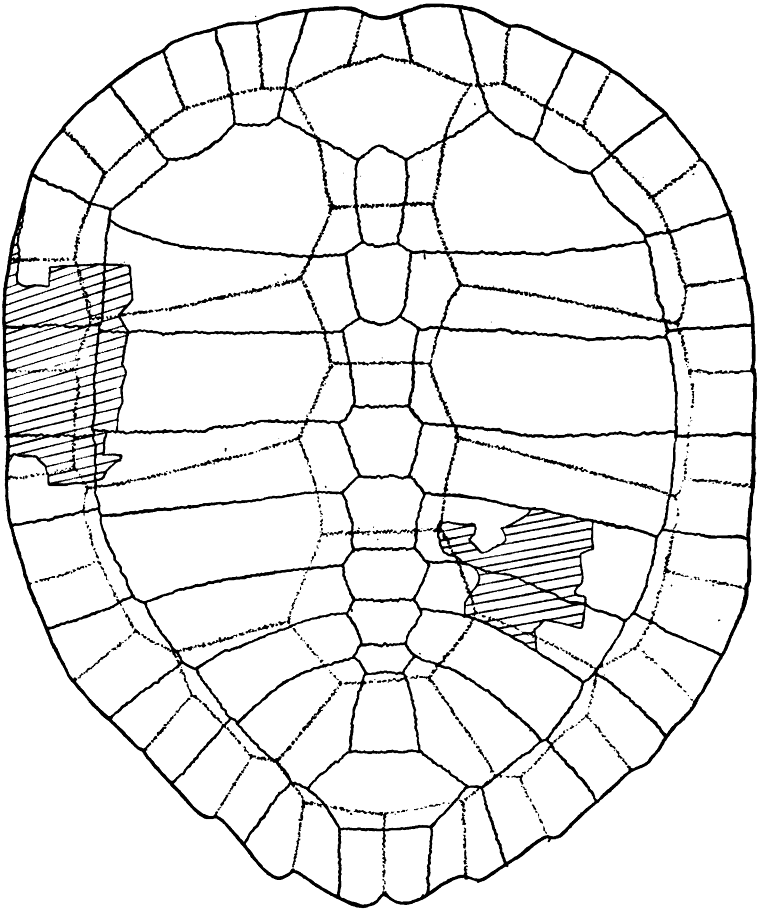

The following are the most important measurements, all parts of the drawings being to scale.

Length of carapace	·303 meters
Width of carapace	·253
Length of plastron	·265
Width of plastron	·144
Length of meso-sternum	·045
Width of meso-sternum	·045

Along with these fossils was an unusual bit of evidence of the river origin of the Titanothere beds, supplementary to that already given by Matthew* and others. On the head of Bear Creek and along the north side of Spring Draw Basin, about thirty feet above the undoubted base of the White River beds,

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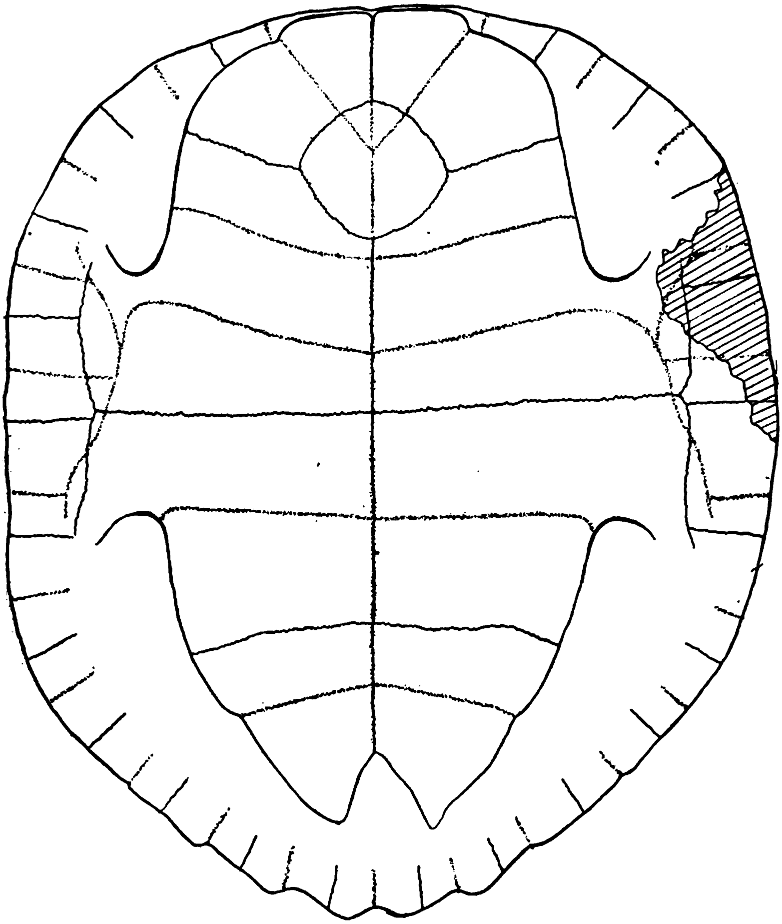


was found a considerable collection of Ft. Pierre fossils. The collection consists of 15 *Baculites ovatus* S., 2 *Baculites grandis* H. & M. Over 100 baculites were seen, but only such as had satisfactory sutures were saved, and a specimen of a Mosasaur

* Matthew, Amer. Nat., vol. xxxiii, 1899, p. 403; Davis, Proc. Amer. Acad. Arts and Sciences, vol. xxxv, 1900, p. 345.

(Platycarpus?) consisting of 20 vertebræ, $2\frac{1}{2}$ paddle pieces and some fragments, 28 bones in all. All of these occurred in concretions similar in shape, size and structure to those in the Ft. Pierre but lighter in color, and stained with hæmatite on the outside and wherever weathered. The baculites occurred over an area about three miles in diameter, in many places in great abundance. However, in none of the neighboring localities did any trace of these fossils occur; although the Titanothere beds were carefully examined for more such material. The species are those not uncommon in the neighboring Ft. Pierre. The underlying Oligocene is mostly the typical white chalk of the formation, with near the base some beds of sand and gravel. In the chalky beds about six feet above the base of the White River formation, and 25 feet below the Ft. Pierre fossils, Titanotherium bones were collected. The beds are clearly Oligocene: the fossils clearly Cretaceous.

But one explanation is at all adequate, and that is, that the river depositing the Titanothere beds supplemented the load of mud its waters were carrying by washing out the Ft. Pierre of its banks, and carried this along, depositing it with the rest. The distance probably was not great. The current must have been rapid however; for the concretions were carried with the fossils. This is certain, for the baculites would never stand transportation without breaking, except in the concretions. Then 28 bones of a Mosasaur were not excavated, carried along and redeposited together, unless held by a matrix. The size of the concretions is from one to three feet in diameter, indicating what the force of the current must have been. Inasmuch as the nature of the material making up the Titanothere beds, and the contained fauna, have already been considered sufficient evidence for the river origin of these beds, such a case of redeposition seems to me conclusive evidence of the flood plain formation of the beds. And the foregoing has given two at least of the forms living in the river.

EXPLANATION OF FIGURES.

FIG. 1.—*Crocodilus prenasalis* nov. spec., snout of specimen No. 1 seen from above. $\times \frac{1}{3}$.
FIG. 2.—Same seen from below. $\times \frac{1}{3}$.
FIG. 3.—*Crocodilus prenasalis* nov. spec., specimen No. 2 dorsal vertebra. $\times \frac{1}{3}$.
FIG. 4.—Tibia of same. $\times \frac{1}{3}$.
FIG. 5.—Femur of same. $\times \frac{1}{3}$.
FIG. 6.—Astragalus of same. $\times \frac{1}{3}$.
FIG. 7.—Dermal scute with two margins sutured. $\times \frac{1}{1}$.
FIG. 8.—Dermal scute with one margin sutured. $\times \frac{1}{1}$.
FIG. 9.—Dermal scute which lay free in the skin. $\times \frac{1}{1}$.
FIG. 10.—*Chrysemys inornata* nov. spec., carapace. $\times \frac{2}{3}$.
FIG. 11.— " " " " plastron. $\times \frac{2}{3}$.

Art. XLIV.—*Emmonsite (?) from a New Locality*; by W. F. Hillebrand.

Dr. Waldemar Lindgren, of the Geological Survey, collected in the W. P. H. mine at Cripple Creek, Colorado, a green mineral which has been observed in other mines there, and which on examination in the laboratory showed close resemblances to the emmonsite described by the writer nearly twenty years ago.* It differed from it, however, in outward appearance by assuming mammillary forms instead of crystalline plates. In its optical properties, so far as they were determinable, there is perhaps no positive disagreement with those reported for emmonsite. Mr. W.T. Schaller reports as follows:

"There are two cleavages, one parallel to *b* (010) and another parallel to a form in the orthozone. Axial plane parallel to *b* (010). Bx_a perpendicular to a cleavage face in the orthozone. The extinction on the clinopinacoid is inclined 25° to 30° to the vertical axis. 2E is approximately 40°. Double refraction medium, and the mineral non-pleochroic."

The gangue in which the specimens were found is granite and schist, close to their contact with a porphyritic breccia, in a vein pocket, at a distance of about 150 feet from the surface. Associated with it was very rich native gold ore and also tellurite, though neither of these was apparent on the few specimens that came to the laboratory.

Like emmonsite, the mineral melts at a low heat to a red-brown liquid, but, unlike it, gives on stronger heating only tellurous oxide with no trace of selenium or selenious oxide. Analysis confirmed the absence of selenium. Its density, too, differs from that of emmonsite, if the determinations, in both cases on scanty material, are to be depended on. After allowing for gangue the original emmonsite was judged to have a density of at least 5, while that of the present mineral is but little above 4·53, after allowing for 22·44 per cent of gangue, consisting mainly of quartz, and to which the specific gravity of quartz was assigned.

In its appearance the present mineral would seem to resemble durdenite more than emmonsite, but the marked difference in water content differentiates it sharply from that mineral, which yields over ten per cent.

After deducting 22·44 per cent of gangue containing over 90 per cent of silica, three portions of from 0·15 to 0·20 gram net weight each gave the following results:

* Proc. Colorado Sci. Soc., ii, 20, 1885.

				Mean.	Ratios.
TeO_2	70·83	71·80	70·20	70·71	3·16
Fe_2O_3	22·67	22·81	22·79	22·76	1·00
H_2O at 100°	4·68	4·82	0·21	0·21	
H_2O above 100°				4·54	1·77
P_2O_5	0·34			0·34	
Al_2O_3		0·58	0·54	0·56	
SiO_2, etc.*				0·88	
				100·00	

Allowing alumina to offset the P_2O_5, though it may belong to a soluble silicate or to the tellurite and a small proportion of iron be demanded for the P_2O_5, the ratios given in the final column result. They are as unsatisfactory as those afforded by the original emmonsite, which were for Fe_2O_3: TeO_2, 1 : 3·65 in the original description and 1 : 3·75 : 1·82 for Fe_2O_3 : TeO_2 : H_2O if the supplementary determinations in this Journal, xl, 81, 1899, are accepted. The presence of tellurite in association with the green mineral suggests a possible explanation of the failure to obtain a simple ratio, though such contamination was not noted in the material analyzed nor on the neighboring gangue. If this explanation is correct, however, the variation from the original emmonsite ratio becomes still more marked. Provisionally the mineral may be regarded as emmonsite.

The above results are given in some detail, notwithstanding their inconclusiveness, because of the importance of accumulating data regarding the as yet small but interesting group of ferric tellurites, and inciting collectors and mining men to careful search for and preservation of further material for more extended study.

Thus far, emmonsite, durdenite, and an unnamed mineral from Cripple Creek, described by Knight in the Proc. Colorado Sci. Soc., v, 66, and affording likewise unsatisfactory ratios, comprise the list of natural ferric tellurites, the formula of no one of which can be regarded as established beyond question.

U. S. Geological Survey, Washington, D. C., Oct. 1904.

* Includes alkalies, traces of magnesia and gold, and a small amount of a metal or metals precipitable by hydrogen sulphide, whose identity could not be established.

ART. XLV.—*The Matawan Formation of Maryland, Delaware, and New Jersey, and its relations to overlying and underlying Formations;* by WM. BULLOCK CLARK.

THE name Matawan was proposed by the author in an article published in the Journal of Geology in 1894 and was there described as equivalent in a general way to the term Clay Marls of Professor Cook. The chief characteristics of this series of strata had been briefly discussed, however, two years earlier in the Annual Report of the State Geologist of New Jersey for 1892. In this earlier publication the separation of the deposits into a lower clayey and an upper sandy member was indicated, although the names Crosswicks clays and Hazlet sands were not introduced until 1897 in an article published in the Bulletin of the Geological Society of America.

The work of the writer on the Cretaceous stratigraphy of the Middle Atlantic Coastal Plain has been conducted primarily for the U. S. Geological Survey, and was started in Monmouth County, New Jersey, beginning in 1891. The results of these early investigations, published the following year in the Annual Report of the State Geologist of New Jersey for 1892, which was accompanied by a "preliminary geological map," represent mainly the conclusions which were reached from a study of that local district. A wider extension of the studies after 1891, both in New Jersey and Maryland, led to the preparation of the fuller article published in the Bulletin of the Geological Society of America in 1897, in which certain modifications were made in earlier views. The practical completion of the detailed mapping of the Cretaceous formations in New Jersey and in Maryland the present season has now led, it is believed, to a fairly close approximation to a correct interpretation of the conditions represented in the entire province between the Potomac and the Raritan rivers. In the light of the Maryland work, the earliest maps prepared in New Jersey have been more or less modified in local details, although the general results remain the same.

In a discussion of the Coastal Plain formations of Maryland and New Jersey, it should be borne in mind that the entire series of Upper Cretaceous deposits amount to scarcely five hundred feet in total thickness, and that the beds, as far as known, are practically conformable throughout. Beginning with clays and sands slightly glauconitic, they pass over into greensand marls. Five formations have been defined and mapped, and several subdivisions of most of these formations described by the writer.

In order that the conclusions reached by the author and his associates may be clearly understood, the following discussion of the stratigraphic relations of the Matawan formation is

introduced. With the extension of the work southward from Monmouth County, and more particularly with the study of the stratigraphy in Maryland, we soon came to the conclusion that the reddish brown sands (Mt. Laurel sands, called Wenonah sand by the New Jersey Geological Survey) beneath the Lower Marl bed (Navesink marls) properly belonged with the Navesink marls and Redbank sands above rather than with the Matawan below. The Redbank sands were found to disappear in about the latitude of Philadelphia, bringing the Navesink marls in Camden, Gloucester, and Salem counties, New Jersey, into immediate contact with the Rancocas marls above, from which, however, they can be separated by their contained fossils and by their more or less distinctive materials. The Monmouth formation was established to embrace the three beds.* In Maryland, however, no such differentiation of the Monmouth is discernible, the only deposits found between the Matawan formation below and the Rancocas formation above being more or less homogeneous red sands, glauconitic from base to top. Earlier attempts to maintain the New Jersey subdivisions in Maryland have not proven satisfactory.† A proper division of the Cretaceous deposits would therefore call for a drawing of the line between the Matawan and Monmouth formations below rather than above the Mt. Laurel sands.

A lens of clays and interbedded sands lying beneath the typical Matawan at Cliffwood, New Jersey, on the shores of the Raritan Bay, and included by the writer in that formation in his "Preliminary Geological Map of portions of Monmouth and Middlesex counties, New Jersey," accompanying the report of the State Geologist for 1892, has been the subject of much discussion of late, although none of the views thus far advanced seem to afford an adequate explanation of the conditions there presented. The clays, which are more or less micaceous and at times sandy, possess many features in common with the typical Matawan deposits above, even to the occurrence now and then of patches of glauconite.‡ The interbedded sands, as well as the lack of continuity of the clay beds, suggest, on the other hand, conditions characteristic of the Raritan, although the deposits as a whole show quite marked differences from the typical

* Bull. Geol. Soc. Amer., vol. viii, pp. 315–358, 1897.

† The idea has been advanced that the Maryland Monmouth may perhaps represent the Mt. Laurel sands alone, and that the Navesink marls along with the Redbank sands have disappeared in Maryland, but the long distance between the last outcrop in New Jersey and the first occurrence on the west side of the Delaware Bay renders it unwise to draw such a conclusion from the data now at hand. The deposits have furnished, to be sure, specimens of *Belemnitella americana*, which is a distinctly lower Monmouth form farther north, but as they did not come from the higher beds of the Delaware-Maryland strata the evidence is not conclusive.

‡ Mr. E. W. Berry, on a recent visit to the locality, removed a small envelope full of glauconitic material from one of these patches below the debatable contact of the Matawan. The writer has also found glauconite in these beds, although the patches are very infrequent.

Raritan beds. The most important feature connected with this occurrence is the presence of a typical Cretaceous marine fauna,* part of the species being similar to the overlying Matawan, and a flora* containing many representatives of genera more recent than those in the Raritan below. Mr. E. W. Berry,† who has recently studied this flora, finds that only 37 per cent of the forms occur in the Raritan and among these the oldest and most characteristic types are lacking. In an earlier communication I referred to the lack of a clear line of separation between these beds and the typical Matawan above. At the time of my first and only study of the occurrence, thirteen years ago, the sections were much less distinctly exposed than at present, slips obscuring the upper beds. I felt in much doubt at the time as to whether the beds belonged to the Matawan above or to the Raritan below, and although I at first regarded them as Raritan and so mapped them, I finally decided to refer them to the Matawan and changed my lines accordingly before publication. On a recent visit to the locality I found the line of contact clearly shown, and it is evident that the Cliffwood clays represent an older horizon than the basal Matawan elsewhere exposed. Messrs. Kümmel and Knapp in the recent Clay Report of the New Jersey Survey, have referred these beds to the Raritan, but from their structural relations, lithologic character, and contained fossils it is apparent that it is equally impossible to refer them to that formation. All of these features indicate that these deposits constitute a transitional zone between the Raritan below and the Matawan above, and that they should be given independent rank as a formation.

A study of the basal contact of the Matawan formation from the Potomac to the Raritan rivers shows that the Matawan rests on successively later deposits northward, thus indicating a gradual transgression of the Matawan over the Potomac formations southward. Near the Potomac river the Matawan overlies the Patapsco formation, but farther north the Raritan soon appears. In approaching the Severn river and on the Eastern Shore of Maryland, deposits that suggest the Cliffwood beds occur between the typical Raritan and Matawan. In Delaware and also in southern New Jersey similar deposits have been found by the author and his associates, marine fossils occurring in the beds at Bordentown. Characteristic concretions of iron carbonate, frequently fossiliferous, have been found all the way from the shores of the Chesapeake to Cliffwood on the Raritan, although marine fossils have not been observed south of Bordentown. These deposits are significant in furnishing the earliest known Coastal Plain marine fauna, a fauna which apparently contained the first strictly marine types of life to migrate into the

* Hollick, A., The Cretaceous Clay Marl Exposure near Cliffwood, N. J., Trans. N. Y. Acad. Sci., vol. xvi, pp. 124–136, pls. xi–xiv, 1897.

† Bull. N. Y. Bot. Garden, vol. iii, No. 9, pp. 45–103, pls. 43–57, 1903; Amer. Geol., vol. xxxiv, pp. 253–260, pl. xv, 1904.

basin of Potomac sedimentation. It is possible that the Island Series of Professor Ward farther north may also prove to be the equivalent of these beds, although the exact stratigraphic limits of the former are not quite clear.

Uhler* in 1892 described what he termed the "Alternate Clay Sands" overlying his Albirupean (in part Raritan) formation in Maryland, and Darton† in 1893 proposed the name Magothy formation for these deposits, stating that they constituted a well-defined stratigraphic unit between the Potomac formation below and the marine Cretaceous deposits (Matawan, etc.) above. He, as well as Shattuck,‡ regarded certain of the clays, which unquestionably underlie the true Matawan formation, as part of the Matawan, and the similarity of the materials would often suggest this reference. Recent work by the writer and his associates both in Maryland and in New Jersey, as well as along the Delaware and Chesapeake Canal§ in Delaware, shows that a series of deposits, lying between the Matawan above and typical Raritan below and consisting of alternating beds of dark clays and light sands, the latter frequently brown in color, or of one or the other, as the case may be, and having a thickness of from 10 to 100 feet or more, can be traced almost continuously from the western shores of the Chesapeake Bay in Maryland to the Raritan Bay in New Jersey. Darton was evidently the first to name this formation should it be ultimately shown to represent a single stratigraphic unit. In the absence of satisfactory exposures in Maryland a critical study of the plant remains is demanded before final judgment can be passed. It is highly probable, however, that the Maryland strata represent a somewhat lower horizon than the fossiliferous beds at Cliffwood, and may be the equivalent, in part at least, of the "laminated sands" which underlie the lignitic beds at Cliffwood. The base of Darton's Magothy may thus prove to be the base of the "laminated sands" and may necessitate the transfer everywhere of certain upper sands hitherto regarded as Raritan to the Magothy-Cliffwood series.

The Matawan formation in New Jersey, as previously stated, has been divided by the author into the Crosswicks clays and Hazlet sands, the former corresponding to the Merchantville clay and the Woodbury clay and the latter to the Columbus

* Uhler, P. R., Trans. Md. Acad. Sci., vol. i, pp. 200, 201, 1892.

† Darton, N. H., this Journal, ser. iii, vol. xlv, pp. 407–419, 1893.

‡ Shattuck, G. B., Md. Geol. Survey, Cecil County Report, pp. 158, 159, 1902.

§ The section in the Deep Cut of the Delaware and Chesapeake Canal is one of the best in the Coastal Plain and shows the Matawan resting on the clays and sands of the Magothy formation, which at this point are in places highly lignitic. The Matawan formation consists at the base of chocolate-colored marls 15 to 20 feet in thickness overlain by black micaceous sandy clays 10 to 12 feet in thickness, which together apparently represent the Crosswicks clays. Above these beds is a more sandy member distinctly glauconitic that may perhaps represent the Hazlet sands farther north. At the eastern end of the Deep Cut the red sands of the Monmouth occur with fossils characteristic of the lower Monmouth in New Jersey.

sand and the Marshalltown sand and clay of the New Jersey Geological Survey.*

The Matawan formation gradually thins from about 220 feet on the shores of the Raritan Bay to less than 20 feet along the Potomac, where the formation finally disappears. The country throughout much of this distance of nearly 200 miles is more or less thickly covered with deposits of Pleistocene age which make it impossible to trace the beds continuously, although the numerous well-borings have greatly aided in the interpretation of the deposits. For cartographic purposes, on the scales adopted by the U. S. Geological Survey and the Maryland Geological Survey, it has not been thought desirable to attempt the mapping of the subsidiary divisions of the Matawan, although this is reported to have been successfully accomplished for the State Geological Survey of New Jersey by Mr. G. N. Knapp, who has recognized four members in the Matawan, known from below upward as the Merchantville clay bed, the Woodbury clay bed, the Columbus sand bed, and the Marshalltown sand and clay bed,† which he has extended practically across the State of New Jersey, although the Columbus sand bed 100 feet thick in Monmouth County is represented as reduced to 20 feet at Swedesboro and "farther southwest it seems to pinch out." These beds, because of the different physical conditions attending their formation, are reported by the State Geologist of New Jersey to show minor differences in their faunas, these faunules being recognized wherever the deposits appear. These subdivisions cannot, however, be satisfactorily recognized in Maryland, where the Matawan possesses greater homogeneity, being throughout predominantly a micaceous sandy clay.‡ Similar faunal differences commonly appear with lithologic variations, and in Maryland many such occurrences have been recognized and described in the Paleozoic and Tertiary formations, although from their size it has not seemed wise to cartographically represent them.

Many attempts have been made to correlate the Atlantic Coast Cretaceous deposits with other American and with European formations. In an earlier paper the author referred to the Senonian and Danian affinities of the higher Cretaceous formations in New Jersey, while the paleobotanists have regarded the lower Cretaceous formations to be the equivalent

* See description of these beds in vol. vi, Final Rept. of the State Geologist of New Jersey, pp. 155–161.

† These names first appeared in print in the Annual Report of the State Geologist for 1898 published in 1899, although the field work was started some years earlier.

‡ The more sandy character of the upper Matawan is still recognized in Cecil County but becomes largely lost in Kent County where the black micaceous sandy clay increases, and is found in the upper as well as the lower beds. Farther south no differentiation in the formation appears possible and the deposits become mainly black micaceous sandy clays throughout, although the few feet of the lower and often slightly darker beds of the undifferentiated red sands above may possibly represent the upper Matawan farther north.

of the Neocomian and Gault of Europe. The Cliffwood clays are considered by Professor Hollick and Mr. Berry to show Cenomanian characteristics in the flora, and a study of the fauna will doubtless throw much important new light upon this division of the Cretaceous.

It is evident, therefore, that the Atlantic Coast Cretaceous formations represent a considerable part of the European series, although the data at hand are insufficient as yet for complete correlation of the several horizons.

In the following table an approximate correlation of the Atlantic Coast Cretaceous formations is suggested.

Age.			Formations.	Members.	
Eocene			Sharkriver 10–15 ft.		
Cretaceous	Upper	Danian	Manasquan 30–50 ft.		Marl and Clay Marl Series
			Rancocas 30–125 ft.	Vincentown Limesands	
				Sewell Marls	
		Senonian	Monmouth 30–200 ft.	Redbank Sands	
				Navesink Marls	
				Mt. Laurel Sands (Wenonah Sand of N. J. Geol. Survey)	
			Matawan 20–220 ft.	Hazlet Sands Marshalltown Sand and Clay bed Columbus Sand bed	
				Crosswicks Clays Woodbury Clay bed Merchantville Clay bed	
	Lower	Cenomanian	Magothy and Cliffwood beds 10-100 ft.		Transitional deposits
		Albian-Neocomian	Raritan 200–400 ft.		Potomac Group
			Patapsco 150–240 ft.		
Jurassic (?)			Arundel 0–125 ft.		
			Patuxent 50–100 ft.		

Geological Laboratory, Johns Hopkins University.

ART. XLVI.—*The Precipitation of Barium Bromide by Hydrobromic Acid;* by NORMAN C. THORNE.

[Contributions from the Kent Chemical Laboratory of Yale University—CXXXI.]

IN former articles from this laboratory,* processes for the separation and determination of certain chlorides, hydrous or anhydrous, by the action of hydrochloric acid have been studied. The present article deals with the similar separation and determination of barium bromide by the agency of hydrobromic acid.

The hydrobromic acid used in the experiments to be described was prepared by dropping from a stoppered funnel liquid bromine into naphthalene dissolved in kerosene, passing the hydrogen bromide evolved through a purifying tower charged in layers with glass-wool and red phosphorus and a water trap, and saturating distilled water with the gas thus purified.

Pure barium bromide was made by dissolving barium chloride in water, precipitating barium carbonate by ammonium carbonate and ammonium hydroxide, washing the precipitate by decantation and dissolving it in hydrobromic acid. This solution of barium bromide was evaporated to dryness and the barium bromide thus obtained was used in the following experiments.

In the first series of experiments a weighed amount of the barium bromide was dissolved in the least volume of water, and treated with hydrobromic acid or with a mixture of hydrobromic acid and ether in equal volumes. The liquid was saturated with hydrobromic acid gas and filtered upon asbestos, and the precipitate washed by a mixture of hydrobromic acid and ether, dried in air bath or over Bunsen flame and weighed as $BaBr_2$. The details of these experiments are given in Table I.

TABLE I.

$BaBr_2$ taken. grm.	HBr. cm³.	HBr and ether. cm³.	$BaBr_2$ found. grm.	Error. grm.
0·2932	30		0·2934	+0·0002
0·1264	30		0·1260	−0·0004
0·1134	30		0·1132	−0·0002
0·1347		30	0·1367	+0·0020
0·1040		30	0·1035	−0·0005
0·0744		20	0·0748	+0·0004
0·1197		30	0·1211	+0·0014
0·4327	30		0·4345	+0·0018

* This Journal (3), xliii, 521 (Mar); (4), ii, 416 (Gooch and Havens); (4), iv, III (Havens); (4), vi, 45 (Havens); (4), vi, 396 (Havens).

Considerable difficulty was had in drying the barium bromide so as to obtain a constant weight, and the barium bromide prepared in the manner described did not dissolve completely. The results of these experiments are thereby lacking in uniformity. Presuming that the source of inaccuracy is to be looked for in the formation of an oxybromide, the precipitate in the next experiments, after filtering upon asbestos, was treated with ammonium bromide and then dried over a radiator,—at first at a low temperature and finally at a temperature high enough to drive off the ammonium bromide. When the thermometer inside of the radiator showed a temperature of 250° C. all the ammonium bromide disappeared and left a barium bromide which gave constant results, as shown in the following table.

TABLE II.

$BaBr_2$ taken. grm.	HBr and ether. cm^3.	$BaBr_2$ found. grm.	Error. grm.
0·1330	30	0·1534	+0·0004
0·1013	30	0·1016	+0·0003
0·2769	30	0·2760	—0·0009
0·2359	30	0·2353	—0·0006
0·1580	30	0·1579	—0·0001
0·2955	30	0·2947	—0·0008
0·2822	30	0·2813	—0·0009
0·1962	30	0·1962	0·0000
0·4127	30	0·4125	—0·0002
0·2751	30	0·2750	—0·0001
0·3181	30	0·3183	+0·0002
0·3049	30	0·3039	—0·0010
0·3754	30	0·3752	—0·0002

These results indicate plainly that barium bromide, prepared in a state of purity and free from oxybromide, may be completely precipitated from solution in water by treatment with a mixture of hydrobromic acid and ether in equal parts and saturation of the liquid with hydrogen bromide.

Some experiments in which precipitation was effected by a mixture of concentrated hydrobromic acid and ether in equal parts, without saturating with the gas, led to similar results. In these experiments the material weighed out was the crystallized hydrous barium bromide, $BaBr_2 . 2H_2O$.

TABLE III.

$BaBr_2 . 2H_2$ taken. grm.	HBr + ether 1:1. cm^3.	$BaBr_2$ found. grm.	$BaBr_2$ calculated. grm.	Error. grm.
0·2008	30 cc.	0·1793	0·1790	+0·0003
0·2041	30	0·1822	0·1820	+0·0002
0·2047	30	0·1821	0·1825	—0·0004
0·2171	30	0·1937	0·1936	+0·0001
0·3101	30	0·2768	0·2765	+0·0003
0·5035	30	0·4496	0·4490	+0·0006
0·5015	30	0·4476	0·4473	+0·0003

The action of hydrobromic acid upon barium chloride was next studied, with or without the presence of salts of calcium and magnesium.

A weighed amount of barium chloride, $BaCl_2 . 2H_2O$, was dissolved in the least volume of water and treated with a mixture of hydrobromic acid and ether in equal volume. The whole solution was saturated with hydrobromic acid gas, filtered upon asbestos, and then, to make sure that no barium oxybromides might be formed, treated with ammonium bromide, dried and weighed as $BaBr_2$.

TABLE IV.

$BaCl_2 . 2H_2O$ taken. grm.	$CaCO_3$. grm.	$MgCO_3$. grm.	HBr + ether 1:1. cm³.	$BaBr_2$ found. cm³.	Theory as $BaBr_2$. grm.	Error in $BaBr_2$. grm.
0·2253	....	....	30	0·2744	0·2741	+0·0003
0·2088	....	....	30	0·2538	0·2540	−0·0002
0·3273	....	....	30	0·3975	0·3982	−0·0007
0·3177	....	....	30	0·3864	0·3865	−0·0001
0·5041	0·5000	....	30	0·6134	0·6143	−0·0009
0·5083	0·5000	....	30	0·6185	0·6191	−0·0006
0·5046	0·5000	....	30	0·6139	0·6136	+0·0003
0·5022	0·5000	....	30	0·6110	0·6104	+0·0006
0·5018	0·5000	....	30	0·6106	0·6108	−0·0002
0·5007	....	0·3000	30	0·6087	0·6092	−0·0005
0·5048	....	0·3000	30	0·6144	0·6142	+0·0002

From these results it is obvious that barium may be separated and determined as the bromide in presence of salts of calcium and magnesium; and it appears also that when the proportion of hydrobromic acid to the barium chloride is that of the experiment and the precipitate ignited with ammonium bromide, the results are in practical accord with those which should be obtained if the precipitate consists entirely of barium bromide.

On the other hand, it appears from the following series of experiments that when a sufficiency of hydrochloric acid is added to the water solution of barium bromide the precipitate falls practically as the chloride.

TABLE V.

$BaBr_2 . 2H_2O$ taken. grm.	HCl used. cm³.	Ether. cm³.	$BaCl_2$ found. grm.	$BaCl_2$ theory. grm.	Error in $BaCl_2$. grm.
0·2044	25	5	0·1279	0·1277	+0·0002
0·2011	25	5	0·1258	0·1257	+0·0001
0·5021	25	5	0·3138	0·3138	0·0000
0·5037	50	10	0·3148	0·3147	+0·0001
0·5020	25	5	0·3135	9·3137	−0·0002
0·3868	25	5	0·2418	0·2417	+0·0001

So it appears that precipitation is complete in presence of a sufficiency of either acid and that the precipitate will fall chiefly as the bromide or as the chloride according to the proportions of hydrobromic acid and hydrochloric acid present.

It was thought a matter of interest in this connection to test the constitution of the precipitates when incomplete precipitation is brought about by addition of one of these acids, the other being present in considerable proportion, though in amount wholly insufficient to produce by itself precipitation in the volume of water used for solution of the barium salts.

Following is the record of experiments in which 1 grm. of barium chloride, $BaCl_2 . 2H_2O$, was dissolved in water, hydrochloric acid added to incipient precipitation, and then an amount of hydrobromic acid which by itself would produce no precipitation in the water solution. The precipitate was dried and weighed, and the content in bromine determined by the method of Baubigny and Rivals.*

$BaCl_2 . 2H_2O$ taken. grm.	Water for solution. cm^3.	HBr added. cm^3.	HCl added. cm^3.	Precipitate. grm.	Bromine in precipitate. grm.	$BaBr_2$ in precipitate. grm.
1.	30	3	22	0·5037†	0·0129	0·0240
1.	42	5	31	0·6241‡	0·0141	0·0263
1.	40	5	30	0·6338‡	0·0202	0·0375

The meaning of these results seems to be that the precipitation of the bromide is induced by the action of the hydrogen chloride upon the solvent, water. The production of free bromine ions and barium ions to the amount of the solubility product of barium bromide in water is, under the conditions, an impossibility. If this be admitted, it seems highly probable that precipitation of barium chloride is likewise conditioned by the action of the hydrogen chloride upon the solvent.

It has been customary on the part of some to explain the similar precipitation of other chlorides soluble in water, like sodium chloride, by large amounts of hydrochloric acid upon the assumption that insolubility is due to increased concentration of the chlorine ions, and such processes have been held to be typical of processes in which precipitation is affected by concentration of the free ions. It seems more probable, however, that it is the action of the hydrogen chloride upon the solvent which is the effective thing in such precipitations, as in the precipitation of barium bromide, after addition of hydrochloric acid, by an amount of hydrobromic acid wholly insufficient to cause precipitation in the water solution.

I wish to express my thanks to Prof. Gooch for suggestions and advice given during the progress of this work.

* Compt. rend., cxxv, 527, 607.

† Dried three months in desiccator over sulphuric acid.

‡ Dried 6 hours at 80° and 12 hours in desiccator over sulphuric acid.

ART. XLVII.—*The Proembryo of the Bennettiteæ;* by G. R. WIELAND. (With Plate XX.)

DURING the course of the preparation and study of large numbers of sections made from many different fossil cycad trunks representing various stages of growth and fructification, no more important feature has been discovered than the *proembryos*, of which various examples have been observed in several different fruits of *Cycadeoidea* from the Black Hills. As no developmental stage, if the archegonia of *Cycadinocarpus augustodunensis* be excepted, has hitherto been observed in any extinct plant, this discovery is of extreme and novel interest. It has, therefore, been deemed appropriate to present a preliminary description, to be amplified and further illustrated in the writer's memoir on the Structure of the Fossil Cycads, now nearly ready for publication by the Carnegie Institution of Washington, under whose auspices these investigations have been pursued.

Amongst the fossil cycads in the Yale collection closely resembling the so-called *Bennettites Gibsonianus* from the Isle of Wight, but still referred by the writer to the genus *Cycadeoidea*, the trunk numbered 393 is very completely silicified, and bears a number of fine ovulate cones. In the various longitudinal and transverse sections cut from these cones, nearly all the tissues are clearly indicated, and the seed bodies have reached approximately the size of those of the type of *C. (Bennettites) Gibsonianus*, found by Solms-Laubach to contain dicotyledonous embryos, nearly or quite filling the seed cavity, and hence exalbuminous, or nearly so. These are the only fossil embryos ever found. In the sections from trunk 393, as is usually the case in silicified plants, the seed cavity is often filled with more or less clear quartz, or by structures and traces of structure which cannot readily be interpreted. But there are in the present instance notable exceptions; a considerable number of the seeds, as one must conveniently call any stage of seed development which is not or cannot be specified, contain well preserved large angular to rounded proembryonal cells. These appear to fill the entire nucellar space in some of the transverse sections. Such an instance, where two adjacent seeds are finely conserved, is shown on Plate XX, enlarged thirty diameters. In other cases the large granular to rounded cells of the proembryo appear to have been but partially preserved, or else to have collapsed, carrying the nucellar wall inwards as if there had been a central cavity in the large-celled mass, as usually

clearly to be seen abutting on the wall of the nucellus. There are also especially to be noted in the transverse sections several irregular ribbon-like traces about the thickness of the cell walls, extending quite across the large-celled mass, filling or nearly filling the nucellus. These traces or rather surfaces occur too often to be considered wholly accidental, but are not supposed to be either suspensors, or tubular öspores, or cells such as precede embryo formation in *Ephedra*. Their fuller explanation doubtless awaits the preparation of more numerous sections and the comparisons they may permit. In some of the sections presumably cutting the upper half of the proembryo, as already hinted, there is a suggestion if not a clear indication that the mass of proembryo tissue was either less dense in its central regions, or, that there was actually present a small central cavity. This important point, which would indicate a fundamental agreement with the existing cycads, cannot be so readily settled as yet, since in no instance has a longitudinal section been cut from a proembryo as well preserved as the two shown in the plate. In one longitudinal section showing the lower two-thirds of a seed it is clear that the lower half of the nucellus was closely filled by the typical large undifferentiated cells making up the mass of the proembryo. In another longitudinal section, the superior end of the nucellus is seen to extend well into the tip of the seed, which is quite filled with the characteristic large-celled proembryo tissue. Unfortunately the middle region is in this instance not conserved.

There is nowhere a distinct indication of the presence of endosperm, or of any differentiation of the large-celled tissue filling the nucellar cavity, into an inner and outer zone. The proembryo tissue appears to be homogeneous throughout, except in one instance where some more elongate cells appear to rest against the nucellar wall. It is, however, to be constantly borne in mind that it is necessary to amplify the series of sections. Structure will be found in many instances illustrating not only all the features of the proembryo, but in all probability the other stages of development, including possibly the early stages of embryo formation; although it may be years before all the facts are learned, since it is so often the fortunate exceptional section which tells the story and yields the reward for the cutting of sections where preservation proves less clear.

Meanwhile it is possible in the light of these newly discovered proembros to make several highly interesting comparisons with existing gymnosperms. The *proembryo* was a term first used by Treub* in describing the embrogeny of *Cycas*. In

* Ann. Jard. Bot., Buitenzorg, ii, 1881, and iv, 1884.

this genus the oöspore enlarges at the expense of the adjacent tissue. Later free nuclei become very abundant in the central region, and then disorganize, all the cytoplasm massing at the base of the spore, and parietally, with a single parietal layer of equidistantly imbedded nuclei, except at the base, where there is some massing of nuclei. *Still later the sac-like cavity of this stage is partly filled up by tissue preceding suspensor development.* The proembryo of *Cycas* is, in a word, sac-like, and the endosperm large, the size of the latter in a way corresponding to the excess in size of the whole seed over that of the Bennettiteæ.

In *Gingko*, after repeated nuclear division of the oöspore, there is no parietal grouping, but instead the oöspore enlarges and comes to be compactly filled with undifferentiated cellular tissue, in which proembryo, suspensors, and embryo are all merged. This must clearly now be regarded as absolutely the most primitive condition known amongst the existing gymnosperms.

In the organization of the *Gingko* embryo, the mass of tissue just noted as filling the entire oöspore takes part, the endosperm being directly invaded without the formation of suspensors. Two cotyledons remarkably like those of the Bennettiteæ in both size and general appearance are produced; but their earliest stages have unfortunately not been figured so far as known to the writer.

Comparison with the other gymnosperms shows that the proembryo of the Bennettiteæ is unique in occupying the entire nucellus, although this character loses not a little of its isolation from the fact that the nucellæ of the existing Cycads are almost of the same size, increase in the size of the seed having been plainly bound up with endosperm development. Again it is supposable that a progressive reduction of endosperm had taken place in the Bennettitæ and was perhaps a cause of the disappearance of the group.

The most distinct agreement of the Bennettitean proembryo is clearly with *Gingko*, long known to have much in common with some ancient Cycadean ancestry or relationship. In both these proembryos, as has been seen, large-celled homogeneous tissue fills the oöspore, and the formation of dicotyledonous embryos takes place without the intervention of suspensors. The present discovery unmistakably determines for the first time that the embryogeny of *Gingko* is the most primitive amongst existing gymnosperms.

Between the existing Cycads and the Bennettiteæ the comparison is a more general one, there doubtless having been agreement in the early history of both, and the more general facts favoring the inclusion of the Bennettiteæ within a single great group, the Cycadales.

Art. XLVIII.—*Minerals from the Clifton-Morenci District, Arizona;** by W. Lindgren and W. F. Hillebrand.

In 1902 an examination was made of the Clifton-Morenci copper district in Arizona. Study of the collections proved the presence of several interesting minerals, a brief account of which is here given. The copper deposits at Clifton and Morenci consist in part of irregular or tabular bodies of oxidized ores in Paleozoic limestones, partly of chalcocite ores connected with fissure veins in a granite porphyry or in the same limestones.

Coronadite.—On the dump of a small shaft on the west end of the Coronado vein, three-fourths of a mile west of Horseshoe shaft, fairly large amounts of a dark metallic mineral were found intimately intergrown with quartz and decomposing into limonite. The vein at this end shows no copper minerals but is stated to contain some gold and its surface ores are reported to have been worked in an arrastre in the early days of the camp. In color this mineral is black and its structure delicately fibrous. The hardness is about 4 and the streak black with brownish tinge.

A thin section proves it to be opaque and in reflected light its fibrous and homogeneous structure is well brought out. It cements angular quartz grains and its secondary nature is clearly indicated. In general aspect it is not unlike psilomelane. A preliminary examination showed that it contained the oxides of lead and manganese; as it did not seem to correspond to any known mineral species, a separation and analysis was made. The results were as follows:

Long continued efforts to secure pure material for analysis by the use of heavy solutions were not attended with success. The ultimate product of specific gravity, 5·246 at 22°, yielded on decomposition by hydrochloric acid a residue of from 6 to 7 per cent, which consisted mainly of silica, with a small amount of alumina, etc. Its presence would not have mattered much had it been quite indifferent to acids, but its partial solubility, as shown by the varying amounts undissolved on different trials and similar varying amounts of alumina and perhaps other minor ingredients found in solution, renders the calculation of molecular ratios not altogether certain in all cases. The composition as found is:

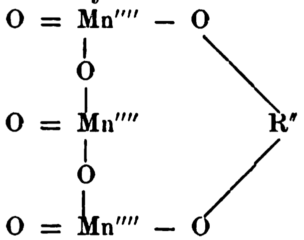
* Published by permission of the Director of the U. S. Geol. Survey.

MnO_2	56·13*
MnO	6·56
PbO	26·48
ZnO	0·10
CuO	0·05
MoO_3	0·34
Al_2O_3	0·63†
Fe_2O_3‡	1·01
H_2O	1·03§
Insol. and silica	7·22
CaO, MgO, Alk., and loss	0·45
	100·00

The material available did not admit of determining quantitatively the vanadium, which may be present in rather more than a mere trace, but neither it nor the phosphorus can influence materially the ratios given below. The vanadium would be effective in two ways: (1) by requiring a base for its neutralization, if existing as an acid constituent, and (2) by liberating chlorine when acted on by hydrochloric acid, and thus affecting the values found for peroxide oxygen. If the iron exists in the ferrous state, it too would affect the values found for the peroxide oxygen and consequently for both the oxides of manganese. Assuming it to so exist and applying the proper corrections, also deducting from the lead oxide an equivalent for the molybdenum, assuming its existence as molybdate of lead, the following are the results:

MnO_2	56.68 ÷ 87	= ·6515		= 3·00
MnO	6·11 ÷ 71	= ·0861		
PbO	26·96 ÷ 222·9	= ·1165		
FeO	0·91 ÷ 72·	= ·0126	} 0·217	= 1·00
ZnO	0·10 ÷ 81	= ·0012		
CuO	0·05 ÷ 79	= ·0006		
H_2O	1·03 ÷ 18	= ·0572		= 0·264

If the mineral is to be regarded as anhydrous, the comparatively simple formula $R''(Mn_3O_7)''$ satisfies the above ratio, and it may be written structurally:



* Mean of 56·10 and 56·13. Total Mn as MnO from $MnSO_4$, 52·38 per cent. Peroxide oxygen 10·31 per cent.

† With a little TiO_2, P_2O_5 and V_2O_5. ‡ State of oxidation not known.

§ Nothing at 100°, only 0·14 per cent below 200°.

in which $R'' = Pb''$ or Mn''. This is to be regarded as a saturated salt of one of the numerous possible derivatives of ortho-manganous acid that may be derived from it by removal of water, in the present case as follows:

$$3H_4MnO_4 - 5H_2O = H_2Mn_3O_7$$

An acid of the same empirical formula would result by removal of two molecules of water from three of metamanganous acid, H_2MnO_3.

It is probably best to rest for the present content with the above relatively simple formula and to regard the water found as due to incipient alteration. But if the water is to be considered as wholly or in part essential, and furthermore constitutional—and this may very well be the proper view to take—then the formula becomes much more complex, namely $R_4''H_2(Mn_{12}O_{29})$, when none of the water is allotted to the foreign matter. This formula is still referable graphically to a more highly condensed manganous acid, and a number of isomers would be possible.

Such intricate formulas as this should not cause the least surprise, however unlikely they may at first appear to be. The great number of manganites, in varying degrees of saturation and hydration, observed in nature and prepared artificially, some of them of even greater complexity that the above, are certainly not all mixtures of only a few simply constituted molecules. A very short study of the graphic formula corresponding to the above empirical formula $R''_4H_2(Mn_{12}O_{29})$ will show what a vast number of closely related bodies are theoretically possible by hydrating the molecule step by step, or by adding to or reducing the number of divalent atoms, or substituting for them those of another valence. Similar varieties in great number would be derivable from other condensed manganous acids of both higher and lower orders, and it is plain that because of the very slight differences in percentage composition between many of them, it is almost as hopeless to expect analysis to reveal the exact empirical formula in the majority of cases as it is for the enormously complex albuminous bodies of organic chemistry. This is especially true because in so many cases the mineral manganites described are far from being homogeneous species. They are either mixtures of two or more of these closely related complex molecules, or else are contaminated by foreign bodies. It is not surprising then that so many compounds of uncertain formula that may be regarded as salts of manganous acid have been prepared in the laboratory or are found in nature. From the known tendency of these bodies to form under laboratory conditions which may very well be repeated in their general character in nature, it is to be expected

that a vast number of mineral manganites should exist, and it ought rather to excite surprise than otherwise if two or more are not formed simultaneously from the same solution. This, together with inherent difficulties of analysis, would offer a simple explanation of the fact that so few of the analyses made lead to rational formulas. If formed from solution their original state might well be one of hydration either as regards water of crystallization or of constitution. The temperature at which the water is expelled in the present case indicates constitutional water.

Our search of the literature has not revealed a native manganite carrying a high percentage of lead, although artificial compounds have been prepared. For this reason, and because of its distinctly crystalline character, the present mineral seems worthy of receiving a specific name. The one we propose is *Coronadite*, after the famous explorer of that portion of the American continent from which the Territories of New Mexico and Arizona have been formed.

Chalcocite (Cu_2S).—The cuprous sulphide is very common in the Clifton district, in fact constituting at present the principal valuable mineral in the ores. It occurs chiefly intergrown with pyrite, in the altered porphyry as disseminated grains or as solid seams or veins which rarely exceed two or three feet in thickness. It is never crystallized but has ordinarily an earthy or sooty appearance and black color; scratching it with a knife reveals the semi-sectile character and metallic luster. In a few small massive veinlets the normal metallic luster and dark gray color appear on fractures; a fibrous or columnar structure of the mineral is known on small seams in shale from the Montezuma mine. The mineral prefers porphyry, and the great bodies of ore now worked all occur in this rock; but it is not entirely unknown from the irregular deposits in limestone generally carrying cuprite and copper carbonates. A partial analysis of massive chalcocite from the Montezuma mine, Morenci, gave 96 per cent Cu_2S and 2·4 per cent FeS_2, the latter probably mechanically admixed.

The chalcocite is everywhere, in this district, a secondary mineral formed by the replacement of pyrite by means of descending solutions of cupric sulphate. The deposition of the mineral was accompanied by the formation of quartz, chalcedony, and kaolin. In the porphyry the chalcocite ore along the veins begins 100 to 200 feet below the surface and continues to a depth of 400 feet, or even more, when it is usually replaced by pyrite, chalcopyrite, and zincblende.

Silicates.

Willemite (Zn_2SiO_4).—This rare silicate of zinc was found by Mr. Boutwell as very small greyish crystals on a fragment

of garnet rock in the Modoc open cut, on the north side of Modoc Mountain. These crystals were identified by Messrs. Pirsson and Penfield of Yale University, who state that the stout hexagonal prisms look exactly like those from the original locality at Moresnet.

Calamine ($ZnOH_2SiO_3$).—Small transparent orthorhombic crystals of calamine were identified on a specimen of decomposed garnet rock from the Shannon mine, just above the lime quarry.

Dioptase (H_2CuSiO_4).—The silicate of copper, dioptase, has been found at only a few localities. Very beautiful specimens, which, however, are by no means common, have long been known from the classic locality, the Kirghese Steppes, Russia, and more recently from the French Congo State, Africa. Dioptase is seldom found in the United States, the only recorded occurrences being at the Bon Ton mines, Chase Creek, near Clifton, Arizona, noted by R. C. Hills,* and from near Riverside P. O., Pinal County, Arizona, noted by W. B. Smith.† Well crystallized specimens of this mineral were found on an old dump of the Stevens group of mines, on the west side of Chase Creek, near Garfield Gulch. They occurred in a small chimney of chrysocolla ore in limestone, now worked out, and the locality is believed to be the same as that described by Mr. Hills. The dioptase crystals were submitted to Prof. S. L. Penfield, who remarks on them as follows:

"The crystals, measuring from 1^{mm} to 2^{mm} in diameter, occur closely grouped together, lining cavities in a brown ferruginous gangue impregnated with amorphous green material which is probably chrysocolla. The color of the dioptase is a beautiful emerald-green. The habit of the crystals, shown by the accompanying figure, is that which is most commonly observed and is especially characteristic for dioptase; prism of the second order $a\,(11\bar{2}0)$, terminated chiefly by the rhombohedron of the first order $s\,(02\bar{2}1)$ and with small faces of the rhombohedron of the third order $x\,(13\bar{4}1)$. As is common on this species, the prismatic faces are vicinal and the s and x faces are striated parallel to their mutual intersection edges, hence the crystals are not suited for giving accurate measurements of the angles with the reflection goniometer. One crystal was measured, and the angles of one of the rhombohedral zones, given below, are sufficiently close to the calculated values to establish the identity of the forms.

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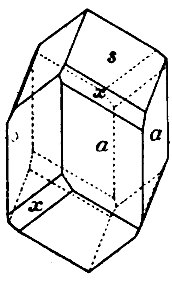

* This Journal (3), vol. xxiii, p. 325, 1882.
† Proc. Colorado Sci. Soc., vol. ii, p. 159, 1887.

				Measured.	Calculated.
$a\ x$,	$11\bar{2}0$	$13\bar{4}1$	=	28° 55′	28° 48′
$s\ s'$,	$02\bar{2}1$	$\bar{2}021$	=	83 48	84 33
$s'\ a''$,	$\bar{2}021$	$\bar{1}\bar{1}20$	=	48 18	47 43

By crushing some of the material, imbedded in oil under a cover glass, and examination in convergent polarized light, occasional fragments were found which gave a normal uniaxial interference figure, with numerous rings indicating high birefringence. The character of the birefringence was found to be positive. Thus in all of its crystallographic and optical relations the material studied is like typical dioptase from other localities."

Chrysocolla ($CuSiO_3+nH_2O$). — This mineral occurs very commonly in the oxidized part of the deposits, but does not, except in some cases, constitute an important ore. On the whole, it is more abundant in the deposits in porphyry and granite than in those contained in limestone. The usual bluish green or dirty green colors and conchoidal fracture characterize it. It occurs in seams or coatings at many of the mines: abundantly in the Mammoth mine on contact fissure between porphyry and limestone; at several prospects on the Stevens group in Chase Creek near Garfield Gulch; in the Terazas fissure vein in porphyry near Metcalf; at the Metcalf mines and many of the prospects between that place and Morenci; at the Modoc open cut, Morenci. Technical analyses of chrysocolla ore from Terazas mine by the Arizona Copper Company gave

SiO_2	31·65
CuO	34·90
H_2O	26·30
Al_2O_3	3·80
Undetermined	3·35
	100·00

Normal chrysocolla should have 34·2 per cent SiO_2, 45·2 per cent CuO, and 20·5 per cent H_2O, but the analyses show great divergency, many probably being mixtures. Moreover, what has been called chrysocolla probably includes two mineral species.

The optical characteristics of chrysocolla seem imperfectly known. Dana states that it is cryptocrystalline, while many other text-books, notably one issued in 1902 by Professor Miers, call it "amorphous."

In most cases the mineral indeed seems cryptocrystalline with bluish gray colors of interference. But this is by no means universal.

Chrysocolla from the Modoc open cut appears as mammillary crusts of bluish green color on "copper-pitch ore." The latter is isotropic and undoubtedly a distinct mineral from the chrysocolla, of brown color in varying tints, some of it opaque and showing evidence of concentric deposition. On top of the chrysocolla are thin crusts of quartz and some calcite. The chrysocolla has three different structural forms, as seen under the microscope: (1) The dominant mass is a cryptocrystalline to microcrystalline aggregate of particles with high birefracting index; (2) very fibrous and felted aggregates of same substance giving undulatory effects between crossed nicols and medium high colors; (3) fibrous crusts on top of 1, or also in thin layers between masses of 1, the individuals having such a remarkably parallel orientation that the aggregate of them appears almost like single crystals between crossed nicols, with black shadows sweeping across them when the table is turned. The extinction is parallel to the fibers, double refraction strong, about like augite, character negative. The same optical characteristics were repeatedly observed in thin sections of chrysocolla from Metcalf and other places. Reniform deposits were sometimes noted, the center of cryptocrystalline material coated with coarsely fibrous and highly birefringent material.

Sections from the Coronado and Metcalf mines often showed pseudomorphs of pyrite consisting of a shell of limonite with kernel of fibrous chrysocolla.

The observations of Jannettaz* on chrysocolla from Boleo Baja, California, Mexico, led to the same results as described above, but seem generally to have been overlooked by editors of text-books.

Copper pitch ore.—Under this old German name is described a dark brown to black substance, sometimes dull but generally with glassy to resinous luster; hardness about 4; streak dark brown. It occurs among the products of oxidation of the deposits in limestone, as at the Detroit and Longfellow mines and Modoc open out at Morenci, and is associated with azurite, malachite, and chrysocolla, often enclosing these minerals or replacing in branching veinlets, together with azurite, a shale-like mass, probably largely composed of kaolin. In thin section it is sometimes opaque, but often also translucent, gradual transitions obtaining in the same section, and occurs in irregular or concretionary masses, often containing small embedded crystals of a doubtful mineral, possibly a silicate of zinc. Between crossed nicols the translucent mineral always proves entirely isotropic and, except for varying depth of color and the small crystals mentioned, entirely homogeneous.

* Bull. Soc. Min. Paris, 1886, ix, 211.

A rough preliminary analysis of selected pitch black material from the Detroit mine gave

CuO	28·6
ZnO	8·4
MnO_2	21·2
$Fe_2O_3+Al_2O_3+P_2O_5$	4·0
Insoluble in H,Cl	22·8
Ignition loss 16·3, less oxygen due to conversion of MnO_2 to Mn_3O_4	13·7
	98·7

Similar material surmounted by crusts of chrysocolla from the Modoc open cut contained much MnO_2, with a good deal of CuO and ZnO, and is thus evidently the same substance. Manganese is largely but not certainly wholly present as MnO_2. The insoluble portion consists of silica, is wholly separated by acid without need of evaporation, and is nearly all soluble in dilute potassium hydroxide. It is not possible to say whether silica is in combination or as opal, but it cannot be present in any other form.

Most of these copper pitch ores, known from many districts, have been described as impure chrysocolla. As shown by the optical characteristics, they are not however a mixture and they certainly do not contain any chrysocolla, the characteristics of which are very different. They probably represent a series of closely related compounds, the chemistry of which has not yet been fully elucidated. Prof. G. A. Koenig* describes a similar mineral with the same isotropic character from Bisbee, and names it melanochalcite. Its composition is different, containing

CuO	76·88
SiO_2	7·80
CO_2	7·17
H_2O	7·71
ZnO	0·41
FeS_2	0·07
	100·04

Prof. Koenig considers it as most probably a basic salt of an ortho-silico-carbonic acid. No carbon dioxide was found in the Morenci minerals. In conclusion, it would seem that the chemistry of these copper pitch ores would bear further examination.

Morencite.—In a lime shale on the intermediate level of the Arizona Central mine, Morenci, 200 feet below the surface,

* This Journal, xiv, p. 404, Dec. 1902.

brownish or greenish spreading mases were found, containing brownish yellow, silky fibrous seams. The enclosing material consists largely of the same material as the seams, but impure and mixed with a little chlorite and pyrite: The whole bears evidence of being a product of oxidation of some contact metamorphic mineral.

The fibrous mineral on the seams forms a felted aggregate as seen under the microscope, but it is well individualized and contains few impurities except a little pyrite and chlorite. The minute fibers are brownish yellow and slightly pleochroic, being darker when parallel to the principal section (opposite the behavior of biotite); the birefringence is strong and extinction strictly parallel to the fibers. No mineral corresponding to this has been described, but, although its individual character is beyond doubt, the analysis does not lead to a satisfactory formula. The material for the analysis was picked out carefully under the lens and, examined under the microscope, it proved satisfactorily pure.

The analysis afforded the results of the first column of figures below. In deducing the molecular ratios of the second column, there has been deducted sufficient lime to form apatite with the phosphoric oxide.

				Molecular ratios.
SiO_2	45·74	757		= 10·71 or 11
TiO_2	trace			
Al_2O_3	1·98	019	205	= 2·90 " 3
Fe_2O_3	29·68	186		
FeO	0·83	011		
MnO	trace			
CaO	1·61	027	141	= 2·00 " 2
MgO	3·99	100		
K_2O	0·20	002		
Na_2O	0·10	001		
H_2O 105°	8·84	491		= 6·96 " 7
H_2O 150°	0·12			
H_2O below redness	4·27	282		= 3·99 " 4
H_2O redness	0·69			
CuO	little			
FeS_2	0·66			
P_2O_5	0·18			
	98·89			

It would seem from the temperatures at which the water is driven off that this must exist in two conditions, and that four-elevenths of it must be held more securely than the remaining seven-elevenths. The attempt to account for four molecules of water as constitutional, however, led to no simple or seemingly

probable formula, whereas if all water is excluded the ratio is that of a metasilicate—$R''_3R'''_6(SiO_3)''_{11}$. On the other hand, to include the whole of the water as essential to the silicate molecule, for which there is little ground in view of the ease with which most of it is expelled, leads to an orthosilicate ratio—$R'_{22}R''_3R'''_6(SiO_4)''''_{11}$.

On the whole, considering also the bad summation of the analysis, it is more rational to regard the mineral as a hydration product of an original metasilicate molecule than to attempt to construct a complex formula which could have but a very doubtful value. Considering that the mineral is not a mixture, but optically well individualized, we have, after some hesitation, thought best to designate it by the name morencite, derived from the locality in which it was found.

Libethenite ($H_2Cu_4P_2O_{10}$).—This hydrous, basic phosphate of copper was found 30 feet below the adit level of the Coronado lode, in the main shoot. It is a matter of interest to record its occurrence, for this rare mineral has never before been noted in the United States. It occurs in small crystals, less than 1^{mm} in length, deposited in cavities and seams in a quartzite gangue. The mineral was identified by Prof. S. L. Penfield, who also kindly measured and figured the crystals. Prof. Penfield describes the occurrence as follows:

"The only associated minerals are occasional clusters of minute quartz crystals and small tufts of radiated malachite needles. The color of the libethenite varies from light to dark olive-green, depending upon the size of the crystals. The habit of the crystals, as shown by the accompanying illustration, is a combination of the prism *m* (110) and brachydome *e* (011), which is exactly like that commonly observed on libethenite from foreign localities. On an occasional crystal the brachypinacoid *b* (010) was also observed. Although the crystals are brilliant, the faces are generally vicinal and give uncertain or multiple reflections of the goniometer signal. The best reflections were obtained from the faces of the dome *e*, and three measurements of $e \wedge e'$, $011 \wedge 0\bar{1}1$ gave 69° 52′, 70° 18′ and 70° 14′. The last measurement, obtained from the best reflections, is close to the value, 70° 8′, obtained by Rose. The best measurements of the prismatic angle gave $m \wedge m'''$, $110 \wedge 1\bar{1}0 = 87°\ 11'$, which, considering the vicinal character of the prismatic faces, is reasonably close to the value of Rose, 87° 40′, as given in Dana's Mineralogy. A small crystal resting on a prismatic face, when examined in convergent polarized light, showed an optical axis nearly in the

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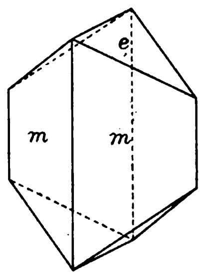


center of the field with the dark bar running at right angles to the vertical axis, thus indicating that the optical axes are in the plane of the base, as determined by Des Cloizeaux. The presence of copper, water and phosphoric anhydride was determined by chemical tests."

A more detailed search would probably reveal small quantities of phosphates from other mines near Morenci. They are certainly not abundant.

Brochantite ($H_6Cu_4SO_{10}$).—This basic sulphate of copper is usually supposed to be one of the rarer minerals. It was, however, discovered at a few places near Metcalf and Morenci, in well developed crystals, and this led to a systematic microscopic examination of the green ores, hitherto supposed to be malachite. The result was surprising, as the mineral was proved to be of extremely common occurrence, mostly intergrown with malachite, which had effectively masked its presence. It is believed that a careful examination of many so-called malachites from other districts will disclose the overlooked importance of brochantite as a copper ore.

Brochantite is frequently crystallized in the short but stout rhombic prisms combined with dome and brachypinacoid characteristic of the species. Needle-shaped and flat crystals are more rare. The crystals are usually of small size and frequently microscopic. It occurs as lighter or darker emerald-green crusts on limonite or sericitized porphyry from the Red ore body in the Shannon mine, from the Metcalf mines and many other places; as fine-grained aggregates in altered porphyry at the Shannon mine, near the surface, and constituting valuable ore with up to 30 per cent copper; from croppings of the King vein, filling seams and coating porphyry fragments as flat pieces or even foils with almost pearly luster; from the croppings of the Copper Queen mine between Morenci and Metcalf, here as flat stellar aggregates of bluish green foils; at many places near Morenci, as, for instance, Copper Mountain and Montezuma mines, at the latter locality replacing chalcocite. It would probably not be found absent from any mine in the district containing oxidized copper ores. Malachite often develops later than the brochantite.

On the whole, the mineral is most abundant in fissure veins in porphyry, though also occurring in the irregular deposits in limestone.

Brochantite has an excellent cleavage parallel to the brachypinacoid. The macropinacoid is the axial plane and the acute bisectrix is seen emerging in cleavage foils. Pleochroism very slight. Birefringence much lower than malachite, about equal to that of augite. This, as well as the absence of twins, distinguishes brochantite from malachite. The reaction for sulphuric acid is of course a valuable aid.

Spangolite ($H_{18}Cu_6AlClSO_{19}$).—This peculiar mineral, essentially a highly basic chloro-sulphate of copper and aluminum, was discovered and described by Prof. S. L. Penfield* some fifteen years ago. The specimen came from some point within 200 miles of Tombstone, Arizona, and probably from one of the great copper camps of the territory. Somewhat later it was identified by Prof. H. A. Miers on two specimens from Cornwall, England, but the American locality has not yet been found. It is, therefore, a matter of interest to record its discovery on some specimens from the Metcalf mine of the Arizona Copper Company, taken from the workings in the great open cut not more than 100 feet below the surface. These specimens consist of white sericitized granite-porphyry, in part silicified, and traversed by veinlets and irregular masses of cuprite; the cuprite contains native copper and is covered by crusts of malachite, brochantite, and chrysocolla. A soft and scaly bluish green coating on the chrysocolla proved to consist of microscopical hexagonal crystals or cleavage foils, remaining dark between crossed nicols. The mineral was identified as spangolite, a determination in which Professor Penfield concurred. No measurable crystals were found and the mineral is very inconspicuous. It is difficult, if not impossible, to obtain material entirely free from accompanying minerals.

Selected bluish flakes from this specimen gave tests for water, and the sulphate and chlorine ions, besides copper. There was too little of this pure material to permit of a test for alumina, but the mixed copper minerals composing the greater part of the specimen showed the presence of this body. It seems therefore probable on these grounds alone that the bluish flakes are spangolite. Vanadium, phosphorus, and arsenic are absent.

The closed-tube reactions of the mixed copper minerals are very striking. Water is given off first. Then appears suddenly a white sublimate ($AlCl_3$?) near the assay, which seems to form or at once change to minute colorless drops. This deposit can be driven slowly up the tube, followed at its lower, sharply defined edge, by dark yellow-brown drops ($CuCl_2$?), which on cooling solidify to greenish crystalline aggregates, and the part of the tube between them and the assay shows under the lense delicate feathery crystallizations like frost markings on window panes. Down in the flame the glass becomes colored red (Cu_2O ?) and in parts yellow. On charcoal the blowpipe flame is colored azure blue and at the same time green.

In order to compare the above closed-tube behavior with that of undoubted spangolite, a small fragment of the latter, offered by Dr. Penfield, was tested. It gave water and then a white

* This Journal, 1890, vol. xxxix, pp. 370–378.

sublimate like the one above mentioned, followed by a dark olive-brown liquid, which on cooling passed though lighter shades of color and solidified as a bright green ring. In general this behavior is very like that of the mixture under examination from Clifton.

Gerhardtite ($H_6Cu_4N_2O_{12}$).—The cliffs of granite-porphyry in the deeply eroded Chase Creek Canyon at Metcalf in many places show a conspicuous and extensive bright green coating of some copper mineral, which, no doubt, is formed by the trickling of atmospheric waters over and through rocks containing a small percentage of copper. This is not surprising, for porphyry in this vicinity is altered throughout by quartz cementation and disseminated cupriferous pyrite. This "green paint," as it is frequently called, is not soluble in water, and more closely examined consists of small dark green, roughly mammillary forms, coating the rock to a thickness of a few millimeters. Examination by the microscope fails to reveal any recognizable mineral in the cryptocrystalline mass.

Chemical examination led to the interesting result that the copper minerals present consist of a nitrate and a chloride, neither of which has been found elsewhere in the mines of the district. Detrital grains and some silica seem associated with these compounds. The nitrogen seems difficult to account for in the absence or scarcity of animal substances which might have yielded it. Possibly it is contained in the porphyry.

The closed-tube reactions of the copper minerals forming the mixture on this specimen are as striking in their way as those of the mixture containing spangolite, described elsewhere. Water first appears, then brownish nitrous vapors, followed by a sublimate which is not very volatile, becomes black on further heating but on cooling yellow-brown. The glass at the bottom of the tube is often yellow-brown when cold. After some hours the sublimate nearly disappears or becomes greenish from absorption of water. If the water which condenses in the upper part of the tube on first applying heat is driven out by the flame, and the mouth of the tube is held in the flame, this is colored deep green by a volatile copper compound (chloride ?). On charcoal the flame is azure blue and at the same time green. Vanadium is absent.

The mixture contains presumably the basic nitrate gerhardtite and a chloride which is perhaps atacamite. Spangolite, the chloride, can hardly be present, for the slight amount of SO_3 shown by test does not seem sufficient to account for the large amount of chloride.

The only place from which gerhardtite has previously been identified is at Jerome mines in the central part of Arizona, associated with cuprite and malachite. It was discovered there by Messrs. H. L. Wells and S. L. Penfield.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Conversion of Ammonia into Nitrites and Nitrates.* — It has been known for a long time that when air acts upon metallic copper in presence of ammonia solution, a formation of ammonium nitrite takes place along with the solution and oxidation of the copper, and it has been found, also, that atmospheric oxygen is taken up by a solution of cupric hydroxide in ammonia, with the formation of nitrite. The first of these reactions gives a small yield of nitrite in comparison with the amount of copper oxidized, while the second one takes place very slowly. W. Traube and A. Biltz have, therefore, investigated the electrolytic oxidation of ammonia in the presence of cupric hydroxide, and have found that when an ammoniacal solution of sodium hydroxide containing dissolved cupric hydroxide is electrolyzed, nearly all the oxygen liberated at the anode is utilized in converting ammonia into the nitrite. Electrodes of platinum and iron foil were used for the experiments; the latter being scarcely attacked in the alkaline solutions. When the electrolysis was prolonged it was found that the nitrite was completely oxidized to nitrate. It was found that the process gave a high percentage of efficiency in the use of the electric current on the small scale used in the laboratory, but it has not yet been ascertained that this interesting method will prove economical as a manufacturing process on the large scale.—*Berichte*, xxxvii, 3130. H. L. W.

2. *Is Tyndall's Optical Method Capable of Showing the Presence of Molecules in Solutions?*—It has been shown by Spring that it is possible to obtain aqueous solutions in which a powerful ray of light is invisible, just as Tyndall found, long ago, that such a ray was invisible in properly purified gases. Lobry de Bruyn and Wolff have recently made experiments which seem to indicate that large molecules in solution have an action upon the ray of light which is similar to that of ultramicroscopic, suspended particles. Their results are perhaps not yet conclusive, but if work on a larger scale and with better apparatus confirms these preliminary results, it will not be easy to distinguish between real and pseudo-solutions (e. g. colloidal solutions of metals), by means of the action of light.—*Recueil, Pays-Bas*, xxiii, 153. H. L. W.

3. *A New Modification of Silicon.* — Moissan and Siemens have found that silicon is more soluble in molten silver than in zinc. It was observed, moreover, that a part of the silicon was readily soluble in hydrofluoric acid, although it separated in a crystalline condition when the silver solidified. Thus, upon saturation, silver was shown to dissolve the amounts given in the following table:

Temperature.	Total Si.	Soluble.	Insoluble.
970°	9·22%	5·35%	3·87%
1150	14·89	4·02	10·87
1250	19·26	3·66	15·60
1470	41·46	6·63	34·83

It was found that when the metallic silver was only partly saturated with silicon, the proportion of the soluble modification was greater, so that when only about 2 per cent was present it was practically all soluble in hydrofluoric acid. This new modification of silicon forms thin, yellow, transparent plates, the color of which resembles the crystallized silicon made with aluminum. Its specific gravity does not vary notably from that of the insoluble modification.—*Berichte*, xxxvii, 2540. H. L. W.

4. *Phosphorescent Zinc Sulphide.*—It has been supposed that chemically pure zinc sulphide was required for the preparation of the well-known phosphorescent blende screens. In preparing such screens Grüne noticed, however, that the results were very variable, and when particular care was taken to use very pure zinc salts, the phosphorescence became weaker than usual. From this it was evident that traces of foreign substances improved the luminosity of the material, and direct experiments showed this to be the case. Copper was found to be the most satisfactory impurity, and less than 1/10,000 of this sufficed to produce a magnificent green phosphorescence. Silver, lead, bismuth, tin, uranium, and cadmium also gave good products, while iron, nickel, cobalt, and chromium gave negative results. When manganese was present in the zinc sulphide a very peculiar product was obtained which phosphoresced with a yellowish red light and became very luminous when it was rubbed or scratched.—*Berichte*, xxxvii, 3076. H. L. W.

5. *Atomic Weight of Rubidium.*—An elaborate investigation of the value of this constant has been made by E. H. Archibald of McGill University, Montreal. Great care was used in purifying the material, particularly in separating the last traces of potassium and cæsium, and several samples of different origin, as well as of different treatment in purification, gave only closely agreeing results. The ratios AgCl : RbCl, Ag : RbCl, AgBr : RbBr and Ag : RbBr were determined with very concordant results, giving a final mean value, when oxygen is taken as 16, as 85·485 for the atomic weight of rubidium. This result is appreciably higher than the results of most of the previous investigators, the value adopted in the international table being 85·4.—*Jour. Chem. Soc.* lxxxv, 776. H. L. W.

6. *Radio-active Cinnabar.*—It has been observed by Losanitsch that certain specimens of the mineral cinnabar show a distinct radio-active action upon the photographic plate, but this is not as strong as the action of pitchblende. It is the author's opinion that the radio-active constituent of cinnabar is not identical with radium, and he gives to it provisionally the name radiomercury.—*Berichte*, xxxvii, 2904. H. L. W.

7. *Materialien der Stereochemie;* von C. A. BISCHOFF. 8vo, pp. cxxxvi + 1977. Braunschweig 1904 (Vieweg und Sohn).—The two large volumes under consideration are made up of nine yearly reports on stereochemistry embracing the years 1894–1902. Each year's report is divided into four sections, treating of general stereochemistry, optical isomerism, the geometrical isomerism of optically inactive bodies, and the relations between position in space and chemical reactions. Those who have not followed closely the progress of stereo-chemistry will be surprised that so extensive a work could be written upon the investigations of nine years in this subject, concerning which nothing was heard twenty years ago. Regardless of some defects, such as slight attention to American work, the book will be found indispensable to those who are interested in this line of research. T. B. J.

8. *Die Heterogenen Gleichgewichte vom Standpunkte der Phasenlehre;* von Dr. H. W. Bakhuis Roozeboom. Vol. II, Part I, pp. 467, 8vo (Vieweg und Sohn, 1904).—The first volume of this book has already been reviewed in this Journal [4], xii, 463, 1901. The present volume is devoted to systems made up of two components in which, as solid phases only the components occur, and excluding the cases where solid compounds or mixed crystals are present. Frequent use is made of diagrams and figures in three dimensions. For students of the phase rule this book when finished should take the part that Ostwald's Lehrbuch does for students of physical chemistry in general. H. W. F.

9. *Phosphorescence.*—A long paper on this subject is contributed by P. LENARD and V. KLATT, and relates to the phosphorescence of sulphides of the alkali earths. This phosphorescence is due to those sulphides, to a small trace of certain metals, and to fusible additions. Together with the chemical nature, the physical structure conditions the character of the light. This light appears only at a glow heat, never at a cold or wet stage, and is destroyed by pressure. Care was taken to obtain definitely pure substances. The addition of small trace of metals changes the intensity of the light, and its duration. No displacement of bands in the spectrum was noticed. The authors believe that their study of the peculiarities of the emission bands gives an insight into the complex phenomena of phosphorescence.—*Ann. der Physik*, No. 12, 1904, pp. 225–282. J. T.

10. *Lippman's Color Photography.*—L. PFAUNDLER having at hand a number of Lippman photographs has made a study of "Zenker Streifer" in regard to their bearing on the color of the photographs. These streifer, or bands, are spectra or interference colors produced by the varying thickness of the photographic film. These spectra diffused over the photograph give the colors observed. The Zenker bands show that there are series of color pairs which do not contribute to a correct color mixture but which tend to neutralize to black. The Lippman method is not a full solution of color photography. It is, however, a beautiful and highly interesting physical experiment.—*Ann. der Physik*, No. 12, 1904, pp. 371–384. J. T.

11. *Change of Velocity of Cathode Rays in passing through thin Metallic Layers.*—H. Hertz first observed the passage of these rays through thin metallic screens, and showed that the rays were diffused in their passage. P. Lenard's paper on the passage of cathode rays outside the exhausted vessel into air and through various substances is well known. He found that the rays apparently suffered no change in velocity. W. Seitz came to the same conclusion. Lately E. Gehrcke showed that under constant potential differences a homogeneous beam of cathode rays after reflection from metallic surfaces showed itself non-homogeneous and the beam was spread out into a spectrum. G. E. LEITHÄUSER has extended this work to the study of the possible change of velocity which a homogeneous cathode beam might suffer in passing through thin metallic membranes. He points out that the failure of the earlier observers to notice a change of velocity was perhaps due to their employment of Ruhmkorf coils, and he has worked with a twenty-plate Holtz machine, which gave a constant difference of potential. He thus obtains a change in velocity and confirms Gehrcke's results.—*Ann. der Physik.*, No. 12, 1904, pp. 283–306. J. T.

12. *Insulation in a Vacuum.*—Lord KELVIN calls attention to a confusion of ideas in regard to the conductivity of the ether. He prefers to call the ether a very perfect non-resister of electricity passing through it, and, therefore, that the insulation of electricity in a vacuum is to be explained not by any resistance of vacant space or of ether but by a resistance of glass or metal or other solid or liquid against the extraction of electrions from it, or against the tearing away of electrified fragments of its own substance. Lord Kelvin believes that it is quite true that the extraction of an electrion from the atom is opposed by a definite permanent force which must be overcome before the electrions can be drawn out. He computes the order of such a force.

Between electrodes $\frac{1}{48}$ of a mm. apart raised to a difference of potential of 200,000 volts the electrostatic force between them will amount to 96,000,000 volts per cm. and would give a force of $109 \cdot 10^{-6}$ dynes or 16·6 tons per sq. cm. in the electrostatic field; four times the above electrostatic force, or 1,280,000 C. G. S. units, would give a force of 66·4 tons weight per cm. The breaking weight of the strongest steel wire scarcely amounts to 20 tons per sq. cm. Hence the metallic electrodes under consideration would be broken into fragments. It would, however, bear the 96,000,000 volts or 16·6 tons per sq. cm.

Lord Kelvin believes it would be very desirable that careful experiments should be made with steady current on the highest obtainable vacuna.—*Phil. Mag.*, Oct. 1904, pp. 534–538. J. T.

13. *Slow Transformation Products of Radium.*—Professor RUTHERFORD summarizes the successive changes of the various emanations and constituents of radium and finds that certain suppositiitious products of pitchblende which he calls radium D and E should have very interesting rates of transformation. Radius D

should emit only β and γ rays. The β rays should decay to half value in about forty years. The radium E should emit only α rays and its value should fall to half value in about one year. Professor Rutherford considers whether these two products have been identified by various observers.—*Phil. Mag.*, Nov. 1904, pp. 636–650. J. T.

14. *Text-book of General Physics for High Schools and Colleges;* by JOSEPH S. AMES. PH.D. 768 pp.(American Book Company.) —In this extensive book there are many excellencies at once apparent to a reviewer. The print is all that could be desired and the diagrams are not only clear but, as a rule, exceptionally well designed. So too the pictures, which are presented in ample but not excessive numbers, are good and well chosen. An excellent feature, also, is the short bibliographies at the ends of many of the sections, which may prove especially helpful to a reader remote from a large library.

If we look for a distinguishing characteristic in this work with respect to its predecessors in the same field, we should doubtless find it an unusually frank effort to teach physics by a mere extension of the individual experience of the student. As this is a method which, to many teachers, seems beset with formidable difficulties, one turns with natural interest to the treatment of mechanics, here extended beyond the usual proportion. The definition of Mechanics (p. 33) takes the unusual form "the science of the inertia of matter." Nowhere, however, does the term inertia appear to be defined or used in a quantitative sense. The only definition (p. 14) is given in the following words: "If the motion of a body is changed in any way by means of our muscles, we are conscious of the sensation of force; and the name 'inertia' is given to that property of the body owing to which this is trne." Mass is defined (p. 60) as pure number, consequently force is (p. 60) asserted to be a magnitude of the same kind as acceleration. Such inconsistencies, however, will doubtless be eliminated in revision. C. S. H.

I. GEOLOGY AND NATURAL HISTORY.

1. *The Stratigraphy and Paleontology of the Niagara of Northern Indiana.* Stratigraphy, by E. M. KINDLE: Paleontology, by E. M. KINDLE and C. L. BREGER. Twenty-eighth Annual Report of the Geological Survey of Indiana, 1904, pp. 397–486, pls. 1–25.—This small but important work treats of an area in which detailed stratigraphic and paleontologic work is very desirable because of the present great interest in the Cincinnati axis in relation to the distribution of Silurian faunas.

The Niagaran formations of northern Indiana are very largely covered by drift, so that no complete sections are shown. Well-borings indicate that the thickness for the entire Niagaran limestones, principally magnesian, varies between 250 and 500 feet. Proximity to land is indicated by the considerable variation in

short distances in the texture and composition of the limestones. Further, "local lenses of sandstone have been observed at some localities." In the Niagaran formation of northern Indiana, there is "a notable exception to the nearly horizontal and undisturbed condition which generally characterizes most of the other formations of Indiana." In the upper Wabash valley, "the strata are frequently found to be highly inclined." The dips vary from 5° to 80°.

"The general structure of the Niagara beds of northern Indiana is that of a broad arch with gently sloping sides trending northwest and southeast. It represents a northwestern extension of the Cincinnati geanticline. Its axis, approximately located, enters the state near Richmond, and passes northwesterly in the vicinity of Muncie, Marion and Peru, and continues north of the Wabash through Cass, White, Jasper and Newton counties into Illinois. On the two sides of this line of maximum elevation of the Niagara the Devonian and Carboniferous rocks dip in opposite directions; in Michigan and Ohio, toward the north and northeast; in Indiana, toward the southwest or south" (p. 409). "The arch described above is not the 'Wabash Arch' of Gorby, which apparently was supposed by its author to follow the Wabash Valley in eastern Indiana" (p. 409). "The dips seem everywhere to be quaquaversal, and it is believed that all of the tilted Niagara beds of northern Indiana represent small domes similar to those at Huntington and Wabash" (p. 411). "There is at present no positive evidence as to the nature of the forces which produced the domes. It seems probable, however, that they may be analogous in origin to the 'mud lumps' at the mouth of the Mississippi" as recently described by Harris.

"Whatever the causes may have been which produced the domes, there is clear evidence that they were developed about the close of the Niagara period. Many of them were elevated above the Paleozoic sea, while others probably did not reach its surface. Some of the domes remained above sea level during a considerable portion of the Devonian age, and there is some evidence that others continued as islands to the end of Devonian time."

"The occurrence of outliers of Pottsville conglomerate in the center of the Niagara area of northwestern Indiana near Remington and Jasper indicate that a subsidence occurred after the formation of the Niagara domes which submerged all or nearly all of the Niagara area of that region beneath the Carboniferous sea. The development of the present Niagara arch in northwestern Indiana was, therefore, of much later date and independent of the formation of the Niagara domes. While the domes date back to the end of the Niagara, the Niagara arch is of Carboniferous or post-Carboniferous age."

"The evidence at hand points to a general elevation of the sea bottoms at the close of the Niagara [Guelph] in the area around the northern end of the Cincinnati geanticline."

"A study of the faunas of the region has shown the presence in

it of faunas representing two distinct and successive epochs of the Niagara group." The earlier of these faunas is "correlated with that of the Lockport limestone of New York. The later fauna which has been recognized contains many species of the Guelph limestone fauna of Canada, which has not hitherto been known to occur in Indiana." The lower beds are called the "Noblesville dolomite" because no trace of the Guelph fauna appears in it.

The higher formation is named the Huntington. "The bulk of this fauna consists of a congeries of cephalopod and gasteropod species, mostly of large size, together with a few heavy-shelled brachiopods. Only four of the fifty species of brachiopods which occur in the Noblesville rocks of northern Indiana have been recognized in the collections from Huntington."

Discussion by the Reviewer.—As stated by Kindle, the Niagaran deposits of northern Indiana include two well-marked horizons equivalent to the Lockport and Guelph formations of New York. Clarke has recently shown that the Lockport limestone has in its upper portion a true Guelph fauna; hence it may be said that in a general way the Noblesville and Huntington formations are equivalent to the Lockport and probably all of the Lockport of New York and the Guelph of Ontario. The Noblesville fauna is in the main made up of brachiopods, while the Huntington is essentially a gasteropod and cephalopod fauna.

Another important fact is indicated but not stated by Kindle. This is the absence of the Waterlime horizon in northern Indiana, although it is present over a great length of the state of Ohio. It is true that Waterlime is reported about Kokomo, Indiana, but the eurypterids from here are, with one exception, not those of the Waterlime, either of New York or Ohio. Further, *Conchidium colletti* of Kokomo is of the generic type abundant in the Noblesville, and in no other American place is this genus known above the Guelph. The occurrence here also of a *Wilsonia* (*W. kokomoensis*) is further suggestive of Noblesville. The conclusion seems warranted that the Kokomo cement beds are probably of Noblesville age rather than of the Huntington and especially the Waterlime or Bertie of New York. This conclusion finds further support in the fact that nowhere south of northern Indiana along the western side of the Cincinnati geanticline are known strata having a Guelph fauna. The work of Foerste in southern Indiana, Kentucky, and Tennessee indicates that the Silurian closed with beds not younger than the Lockport. All of Indiana was land from the close of the Guelph to the beginning of Onondaga time. In other words, during this time there was deposited in eastern New York all of the Cayugan, Helderbergian, and Oriskanian—a time of consideration duration. The first succeeding subsidence began in the south (Tennessee), for the Silurian is overlain by Helderbergian rocks of New Scotland age. In the north, subsidence did not take place until just before Onondaga time, since the oldest Devonian strata are of latest Oriskanian age (Decew-

ville) as may be seen about Decewville, Ontario. This subsidence was gradual and came in from the east and southeast, while the other progressed northward through the Mississippi embayment. With the beginning of Onondaga time, submergence was rapid and quite general throughout the Mississippian sea. It should be stated here that while the sea on the west of the Cincinnati axis became extinct at the close of the Guelph, on the east in Ohio it continues well into the Cayugan, as is proved by the presence here of Waterlime beds of the age of the lower Manlius of New York.

A marked peculiarity of the Noblesville assemblage is the almost total absence of corals, although to the south about the Falls of Ohio, and again near the straits of Mackinac, they are present in great variety and abundance. With this exception, the northern Indiana Niagaran fauna is more decidedly that of southern Indiana about the Falls of Ohio than that of northern Illinois and Wisconsin. This is seen by the presence in the Wabash area of the southern forms *Anastrophia internascens*, *Conchidium littoni*, *C. unguiformis*, *Gypidula rœmeri*, *G. nucleus*, *Camarotœchia whitei* (= *C.* sp. undet. of K. and B.), *C. acinus*, *Wilsonia saffordi*, *Atrypa calvini*, *Spirifer foggi*, *S. radiatus*, *S. crispus simplex*, *Cyrtia myrtia*, and *Meristina rectirostris*. Of strictly northern species, there are in the Wabash area *Conchidium multicostatum*, *Spirifer nobilis*, *Amphicœlia neglecta*, *Lituites marshii*, *Illœnus armatus*, *I. insignis*, *I. ioxus*, *Ceraurus niagarensis*, *Sphærexochus romingeri*, and *Dalmanites vigilans*. Nearly all of the latter are free forms, with greater powers of dissemination than the brachiopods. These facts seem to warrant the statement that the Wabash axis was already in existence during Noblesville time, and that while it was more or less of a barrier against the free intermigration of the northern and eastern and southern faunas, it was not a complete barrier. That it was not effective is further seen in the peculiar distribution of *Conchidium*. In the Louisville area during Lockport, or rather Louisville (= Noblesville), time we have *C. complanatus*, *C. crassiplica*, *C. exponeum*. *C. knappi*, *C. littoni*, *C. nysius*, *C. tenuicostatum*, and *C. unguiforme*. In central and northern Indiana, about the same time, there are *C. colletti*, *C. littoni*, and *C. multicostatum*, and, in Wisconsin, *C. crassiradiatum*, *C. greenei*, and *C. multicostatum*. During Guelph time, in the Wabash area, there are *C. laqueatum* and *C. trilobatum*, and in Wisconsin *C. occidentale*. *C. laqueatum* is related to *C. occidentale* of the eastern Guelph, while *C. trilobatum* is unique unless it proves to be a *Stricklandinia*. This indicates that none of the Noblesville *Conchidia* pass into the Huntington, but that the species found in the latter formation come from the eastern Guelph.

That the Wabash axis was in existence long previous to the Niagaran is seen in the distribution of the earlier faunas. The first marked difference in the Ordovician faunas as seen on the

two sides of the Cincinnati geanticline, and especially in connection with the Wabash axis, is in the Richmond faunas situated to the northwest of the latter axis about Wilmington, Illinois, and Delafield, Wisconsin, and that to the south, especially as seen about Madison, Indiana. It is true that these Richmond faunas have many species in common and it is probable that they are not synchronous, so that there may have been land in southern Indiana at the time when the higher Richmond appeared in northeastern Illinois. This may mean that no true axis or "parma" was in existence during Richmond time, but it does seem to show that the Wabash parma at least indicates the strike for the then highest land. During Silurian time, this parma was a bar to the northward spreading of the Clinton and probably, also, of the Waldron formation. In fact, all the post-Clinton Silurian faunas to the north of the Wabash and east of the Cincinnati parmas are, in facies, more decidedly that of New York, while those south and west of the same barriers have another relationship. The fact that all these faunas have species in common goes to show that the Wabash axis was not at all times a complete barrier to the intermigration of faunas or that the Cincinnati axis was crossed by the sea somewhere in Kentucky or Tennessee. The dissimilarities on the two sides of the Cincinnati axis indicate that the Wabash axis had some effect on the dissemination of the faunas.

In regard to some of the species described, it seems desirable to make a few statements. *Trimerella* sp. appears to be a *Monomorella*, because the platform is not excavated, as may be seen in the cast, not having the two cones so characteristic of the former genus. *Stropheodonta corrugata* has been recently studied by the writer in specimens from the Clinton of Pennsylvania, and these prove the species to be a *Rafinesquina*. *Pholidostrophia niagarensis* is probably a *Brachyprion*, as it has radiating striæ. *Orthis flabellites* Foerste is hardly the well-known shell formerly passing in America as *O. flabellulum*. It looks more like forms of the *O. davidsoni* type. *Eatonia goodlandensis* cannot be an *Eatonia* as it has a dorsal sinus, the reverse condition of this genus. It is probably a pentameroid of the genus *Parastrophia*. *Meristina princeps* is known to be a true *Meristella*, and cannot, therefore, be referred to *Meristina*. The Indiana shell seems to be related to *Meristina maria*, if the striæ mentioned are internal markings. CHARLES SCHUCHERT.

2. *Report on an Exploration of Ekwan River, Sutton Mill Lakes and part of the west coast of James Bay;* by D. B. DOWLING.—This is "Part F" of the fourteenth Annual Report of the Geological Survey of Canada. It is particularly interesting on account of the fauna described by Whiteaves. In the Sutton Mill Lakes region, the Cambrian is also exposed and is regarded by Dowling as of the same age as that on the east shore of Hudson Bay, described many years ago by Bell and Low. In the latter region, the quartz conglomerates, quartzites, and sand-

stones, with a heavy trap overflow, attain a thickness of about 2800 feet. "This great thickness is not found on the west side of the bay." In the Sutton Mills Lakes region, 90 feet of sandstones and slates are shown "capped by an extrusive trap showing a thickness of 150 feet." These rocks "present many features in common with those from the Animikie of Thunder Bay." No fossils are mentioned.

Overlying the Cambrian is "a flat-lying limestone, which forms a wide belt around the west shore of James Bay and along the southern shore of Hudson Bay. On the Albany River the upper part of the series is proved to be of Devonian age, and beneath, at a greater distance from the sea, Silurian limestones are exposed. These beds probably overlap any older ones that may be beneath, and rest directly on the Archæan." The Silurian dolomitic limestone "does not appear to be of any great amount, probably not over 20 feet." The geologic series is terminated by Post-Tertiary clays containing *Saxicava rugosa*, *Mya truncata*, *Macoma calcarea*, and *Cardium ciliatum*.

According to Whiteaves, the Silurian fauna consists of 55 species, of which 39 are specifically named, 26 being restricted to the James Bay region. The percentage of new species is therefore rather high, but not greater than one would expect from a region so widely separated from other known Silurian areas. The assemblage both of species and faunal facies is not that of the Rochester or lower Lockport, as none of the characteristic forms of these well-known faunas are present.

On the other hand, it is directly comparable with the Guelph of Ontario and the higher Niagaran dolomites of Illinois and Wisconsin. This is seen in *Pycnostylus guelphensis*, *P. elegans*, an almost total absence of the lower Niagaran corals, cystids, crinoids, and brachiopods, and in the prescence of 2 species of *Trimerella*, 1 *Salpingostoma*, 3 *Gyronema*, and 3 *Bronteus*. C. S.

3. *Zinc and Lead Deposits of Northern Arkansas*, etc. With a Section on the Determination and Correlation of Formations; by E. O. Ulrich. Prof. Paper, No. 24, U. S. Geol. Survey, 1904, pp. 90–113.*—Ulrich's contribution is important because it attempts to correlate the Paleozoic formations of northern Arkansas and southern Missouri with "a standard time scale of the Ohioan Province." By "Ohioan Province" the author means the eastern half of the Mississippian sea, and also objects to using the latter term for this province because the name Mississippian "has a fixed application to the Lower Carboniferous rocks of America." In northern Arkansas, the Paleozoic section consists of the equivalents in the Ordovician of the Oneonta, Shakopee, St. Peter, Lorraine, and Richmond; in the Silurian of the Clinton; in the Devonian of the Chemung, and in the Carboniferous of a complete sequence from the Kinderhook into the Pottsville, except that the Warsaw and Spergen Hill are absent. From this it is seen that great breaks in deposition occur in the Ordovician, and from the basal Silurian through to the Upper Devonian.

* See also p. 394 of the November number.

The Clinton fauna (St. Clair limestone) is interesting because it is of the type found on both sides of the Cincinnati axis, and not that of New York.

The chief interest of this work, however, lies in the Carboniferous formations. As stated above, the Mississippian section is nearly complete and continues into the lower portion of the Pennsylvanian of the Upper Carboniferous. The author's best results are found in his discussion of the "Upper Mississippian formations" and "Early Pennsylvanian formations." It is seen that he here restricts the well-known name "St. Louis" to the formation as found about the city of St. Louis, which does not include the Spergen Hill and Warsaw horizons, usually embraced under this term. The author states that the St. Louis, Spergen Hill, and Warsaw "are readily distinguishable lithologic units, two of them having a wide geographic distribution, and all three occupying definite and distinct positions in the stratigraphic column. Together they constitute a group for which the name Meramec, after the river of that name in Missouri, where all three divisions may be seen, is chosen."

It seems unfortunate that the rules of the U. S. Geological Survey do not permit the use of a term with two values, i. e., as a formation and as a group name. In any event, it would seem preferable that the old and long-established name "St. Louis" should be retained in its present text-book use, i. e., to embrace all the time between the top of the Keokuk and the base of the Chester. Had this been done, the present author's group terms would now be those of other writers; as it is, however, to be up to date, we shall have to write "Meramec" for the old and apparently somewhat indefinite term "St. Louis." We could have more easily adapted ourselves to Meramec as the terminal formation of the group St. Louis.

The Chester of older writers receives here a far greater extension, is elevated to a group term, and includes the St. Genevieve, Cypress, Tribune, and Birdsville formations. The two latter are here embraced under the old name "Kaskaskia" of Worthen, a term that in the past has often supplanted Hall's name "Chester." The Chester group of Arkansas teems with new species.

One of the peculiarities of the Pottsville fauna in Arkansas, or in the area south of Missouri island (here called Ozarkia), is the presence of *Pentremites.* Heretofore this genus was thought to have disappeared in America with the Chester, and stratigraphers have always placed great reliance on this supposed limitation. Its occurrence shows paleontologists how unsafe it is to make correlations depending on single species or genera. It is stated in a foot-note that this interesting fauna will soon be described by Dr. Girty. C. S.

4. *Monographie de l'Ile d'Anticosti* (*golfe Saint-Laurent*); by Dr. JOSEPH SCHMITT. Published by A. Hermann, Paris, 1904, pp. i–vi, 1–367, 12 text-figures and a map.—Since 1896, M. Henri Menier of Paris, France, has been the owner of the island

of Anticosti, and detailed Dr. Joseph Schmitt as resident physician and naturalist. The work cited describes the local geography, history, meteorology, geology, paleontology, botany, zoology, anthropology, maladies of man and animals, agriculture, and resources. There is also a bibliography of the island, 19 pages in length.

The Ordovician and Silurian stratigraphy is described in considerable detail on pp. 65–99. The divisions as established by Richardson and Billings are here accepted. Many of the more important geological localities are shown in full-page half-tones, the best we have seen of that island. The list of fossils on pp. 100–128 gives the horizons and localities for each species, with occasional remarks on certain forms. The book does credit to the present owner of the island, and especially to its author, Dr. Schmitt. C. S.

5. *Handbuch der Mineralogie;* von Dr. Carl Hintze. Erster Band, achte Lieferung. Pp. 1121–1280.—The eighth part of the first volume of Hintze's great work has recently appeared. It contains the closing portion of the sulphur compounds, ortho- and basic sulpho-salts, sulpharseniates, oxysulphides, etc, and the beginning of the oxides. The closing pages are devoted to the species quartz. The part now issued is the twentieth of the entire series, which was begun in 1889.

6. *Volcanic Pipes of Sutherland.* — In the annual report of the Geological Commission of the Cape of Good Hope for 1903, Mr. A. W. Rogers and A. L. duToit give an account of some circular patches and dike-like outcrops of igneous rocks near the village of Sutherland. These "pipes" resemble closely the Kimberly pipes in form and relation to the surrounding rock, and some of them contain breccia similar in character to the diamond-bearing blue-ground of Kimberly. Melilite-basalt occurs in close connection with them, filling some pipes and forming dike-like masses around them. A complete petrographic description is given of these rocks, and the following analysis of melilite-basalt, from the Spiegel River, was made by J. Lewis.

Analysis of melilite-basalt: SiO_2 36·15, TiO_2 2·30, Al_2O_3 15·18, Fe_2O_3 4·87, Cr_2O_3 ·10, FeO 9·11,* MnO ·33, CaO 11·40, MgO 13·63, BaO ·06, Na_2O 2·42, K_2O 1·81, P_2O_5 ·26, SO_3 ·49, H_2O on ignition 1·95, H_2O driven off below 110° C. ·37 = 100·43.

It will be remembered that Professor Carvill Lewis felt very confident that melilite rock was closely connected with the original form of the Kimberly blue-ground, and it seems probable that the Sutherland area presents some of the same geological characteristics as the Kimberly district.

7. *A Treatise on the British Freshwater Algæ;* by G. S. West; pp. xv + 372, with 166 text-figures. Cambridge, 1904 (The University Press).—The need of a modern account of the freshwater algæ has long been felt by English-speaking botanists,

* A little sulphide which would slightly increase the figure for ferrous iron is included. The sulphur present as sulphide is included in the SO_3.

and this need is admirably supplied by Professor West's handbook. On account of the wide distribution of most of the genera described, the book will be welcome in North America as well as in the British Isles. After a short introduction the author discusses the structural peculiarities of the algæ, the methods of multiplication and reproduction, the doctrine of polymorphism and the various theories of phylogeny. The greater part of the work, however, is filled with detailed descriptions of the British genera and of the higher subdivisions, and under each genus the more important species are noted or briefly described. The characters derived from the peculiarities of the chloroplasts are emphasized throughout, and much attention is devoted to the species found in the plankton of lakes and ponds. The clear and accurate figures, nearly all of which are original, add greatly to the value of the work. Professor West includes among the algæ the diatoms and the blue-greens, two groups which many recent writers place apart; he excludes, however, the dinoflagellates and the stoneworts. Six classes are recognized: Rhodophyceæ or red algæ (with 6 genera), Phæophyceæ or brown algæ (with 8 genera), Chlorophyceæ or green algæ (with 130 genera), Heterokontæ or yellow-green algæ (with 8 genera), Bacillarieæ or diatoms (with 37 genera) and Myxophyceæ or blue-green algæ (with 45 genera). The Heterokontæ include a number of forms usually placed among the Chlorophyceæ. A. W. E.

8. *A Monograph of the British Desmidiaceæ;* by W. West and G. S. West; Vol. I, pp. xxxvi+224; 24 colored plates. London, 1904 (printed for the Ray Society).—In the last general work on the British Desmids, published by M. C. Cooke in 1887, 290 species are described. At the present time nearly 700 species are known from the British Isles, and of this number 147 species are figured and described in the present volume. The introductory chapter is devoted to a general account of the desmids and discusses the cell-structure, the variation, the methods of locomotion, the various types of reproduction, the phylogeny and the geographical distribution. This is followed by an analytical key to the 31 known genera, all but 5 of which are British. The descriptions of genera and species which fill the remainder of the volume are unusually full and accurate, and the plate-figures, nearly all of which were drawn by the junior author, bring out clearly the protoplasmic features of the cells and also the peculiarities exhibited by the cell-walls. Under each species the authors note the full synonymy, the measurements of the cells, the known localities in the British Isles and the general geographical distribution; and it is worthy of note that more than half of the described species have already been reported from the United States. The following 12 genera are treated in this first volume: Gonatozygon (5 species), Genicularia (1 species), Spirotænia (14 species), Mesotænium (10 species), Cylindrocystis (6 species), Netrium (4 species), Penium (28 species), Roya (3 species), Closterium (60 species), Docidium (3 species), Pleurotænium (9 species), and Tetmemorus (4 species). A. W. E.

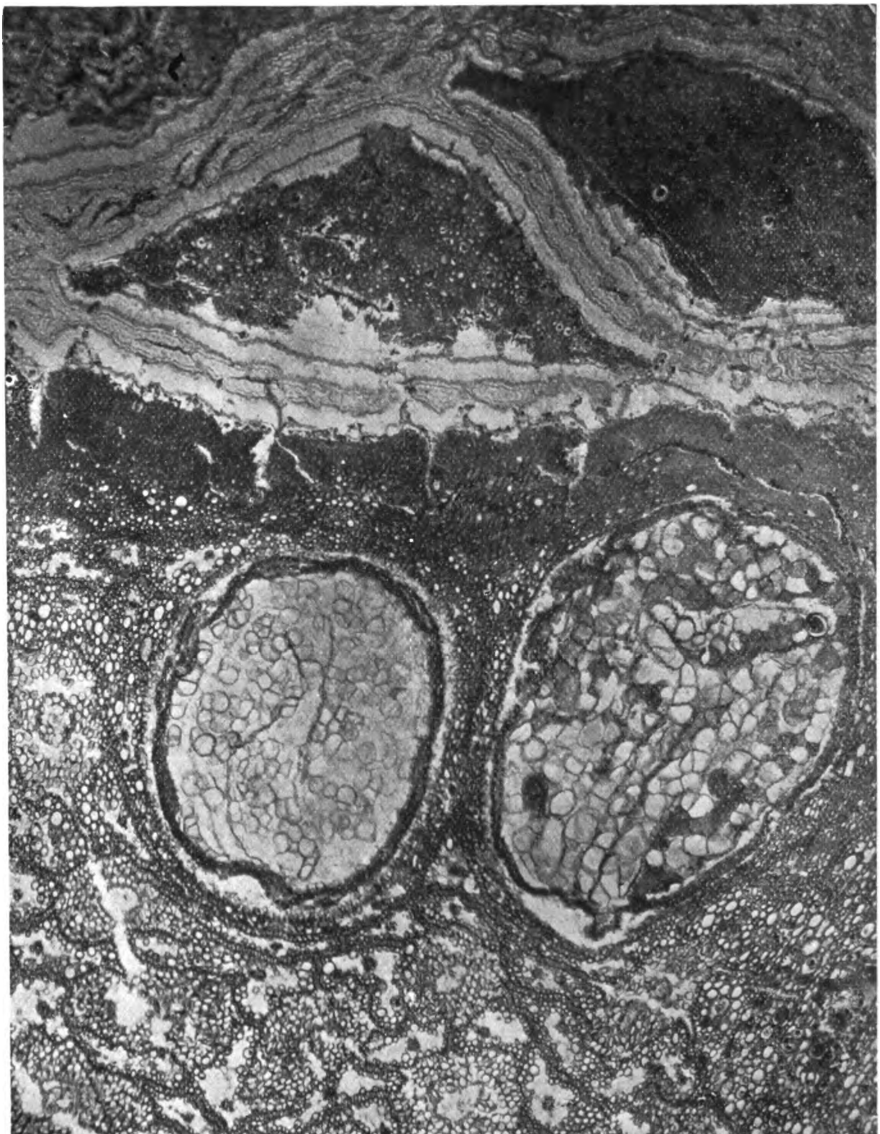
III. Miscellaneous Scientific Intelligence.

1. *The Cyclones of the Far East;* by Rev. José Algué, S. J., Director of the Philippine Weather Bureau, Manila Observatory. Second (revised) edition. Pp. 83 with fifty-four plates. Manila, 1904.—The first edition of this work was published in Spanish in 1897 and embodied the results obtained during the thirty years that had elapsed since the foundation of the Manila Observatory in 1865. The present edition, in the English language, has been enriched by the additional data accumulated since 1897, not only from the Philippines themselves, but also from the adjacent coasts of Asia. The whole work gives a full account of the nature and origin of cyclonic stones and the various meteorological phenomena accompanying them; it also discusses in detail the typhoons of the far East, or the Baguios as they are called by the natives of the Philippine islands. The intensity and destructive character of these great storms in the regions covered by this work give them a peculiar interest and importance, while the author's long study of them has enabled him to present the whole subject with admirable clearness and fullness. The work is at once interesting to the public at large, of high utility to the sailing master because of the many practical suggestions given for his guidance, and also valuable as a scientific contribution particularly because of the discussion of the data in regard to individual cyclones of remarkable character.

The publications of the Philippine Weather Bureau also include a series of monthly Bulletins of the usual scope prepared under the direction of the Director, José Algué: of these the numbers from January to April, 1904, have been recently received.

2. *A Select Bibliography of Chemistry, 1492–1902:* by Henry Carrington Bolton. Second Supplement, pp. 462 (Smithsonian Miscellaneous Collections, part of vol. xliv).—The Select Bibliography of Chemistry from 1492 to 1902, a work of the greatest value to chemists, carried out by the late Professor Bolton, was issued in 1893. A First Supplement, bringing the work down to 1897, was published in 1899, while this Second Supplement, covering the five years to the end of 1902, is now given to the public. Professor Bolton died in November, 1903 while the work was in press and the proof-reading and preparation of the index have been in the charge of Mr. Axel Moth of the New York Public Library.

3. *Kritische Studien über die Vorgänge der Autoxydation;* by C. Engler and J. Weissberg. Braunschweig, 1904 (Fr. Vieweg und Sohn).—This monograph of two hundred pages, dedicated to the memory of Christian Friedrich Schönbein, aims to present a critical review of the scattered literature on the phenomena of so-called auto-oxydation. The authors explain their theory of the nature of auto-oxidative processes. Various types of katalytic reactions are discussed; and the influence of accessory factors, such as acids, salts, heat, light, etc., is considered. In a concluding brief chapter on the rôle of oxygen in living organisms the possible function of the different recently described oxidases, the formation of organic peroxides and the action of katalases is emphasized. L. B. M.



Cycadeoidea Wielandi. S. 394. × 30.

Portion of a transverse section of an ovulate cone, cutting exterior bracts above and two adjacent proembryos filling the seed cavities, as surrounded by the mass of seed pedicels and interseminal scales.

INDEX TO VOLUME XVIII.*

* This Index contains the general heads, BOTANY, CHEMISTRY (incl. chem. physics), GEOLOGY, MINERALS, OBITUARY, ROCKS, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

W

X

Z

ZOOLOGY.